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PROFESSIONAL PAPERS, No. 32

CORPS OF ENGINEERS, U. S. ARMY

MILITARY RAILWAYS

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Corps of Engineers, U. S. Army.

MILITARY RAILWAYS

By Major WILLIAM D. CONNOR,

Corps of Engineers, U. S. Army.

M. Am. Soc. C. E.

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PREFACE.

The lack of a manual on the subject of military railways in our service is sufficient excuse for the following matter. I have compiled from all available books and reports on this subject, and have supplemented this compilation with the results of personal investigation and experience and with suggestions and advice kindly given by many railway officials.

My two great sources of information in the preparation of this text are, I believe, unsurpassed in their respective branches of railway management, and whatever of merit may be found in this manual is largely due to them. On the civil side I refer to Mr. R. H. Aishton, general manager of the Chicago and Northwestern Railway, through whose kindness I was given every opportunity to inspect and study the methods in use on that railway. On the military side I refer to the reports of Colonel Sir E. P. C. Girouard, K. C. M. G., R. E., of the British Army, whose work in Egypt and South Africa has set a high standard for any engineer who in the future may be required to meet and solve railway problems in the theater of war. These reports give the solution of many points as worked out in the field and confirm the main lessons to be learned from the history of the military railways of our civil war.

I wish to express my appreciation of the assistance rendered by the other officials of the Chicago and Northwestern Railway, and especially by those of the Iowa Division, without whose interest and experience I should have been greatly handicapped.

To the officials of the Lake Shore and Michigan Southern Railway and the New York Central and Hudson River Railroad I am indebted for corroboration and clearing up of many points on which I was still undecided after leaving the Chicago and Northwestern Railway.

In the preparation of all the subject matter on switches, turnouts, and crossovers, and for Tables IX, XIX, and XX I am indebted to the kindness of Prof. Wm. H. Searles, C. E., Mem. Am. Soc. C. E., whose Field Engineering was of the greatest assistance in the preparation of diagrams and formulæ relating to the subjects mentioned.

To Mr. W. L. Webb, C. E., Mem. Am. Soc. C. E., I am indebted for Table XI and for many valuable suggestions arising from his book on Railroad Construction.

Notes on Track, by Mr. W. M. Camp, C. E., Mem. Am. Soc. C. E., has been invaluable in its help by corroboration of details and was used especially on the subjects of rapid track laying and yards.

Table X is from the Mathematical Tables of Gen. H. H. Ludlow, U. S. Army; Tables XXI and XXII, from Land Surveying, by Mr. F. Hodgman, M. S., C. E., both of whom kindly gave permission to use their tables.

In the Detailed History of the Railways in the South African War, published by the Royal Engineers Institute, Chatham, England, is doubtless the greatest amount of data on military railways that has ever been gathered together. I have constantly consulted this work and can not overestimate its value and assistance.

Mr. Bailey, of Barnum & Bailey's Circus, who has worked out a remarkable system in loading and unloading vehicles and animals from trains, gave valuable assistance on these two subjects.

Other sources of information were:

Military Railways (text-book at Chatham, England).
Engineer Field Manual, U. S. Corps of Engineers.
Records of the Rebellion.
Professional Papers, Royal Engineers.

Lieutenants James G. Steese and Glen E. Edgerton, Corps of Engineers, assisted me by reviewing the manuscript.

The text of this subject was written in 1905 and was then laid aside for four years. All notes were lost or destroyed and therefore I am unable to recollect the sources of much of my information. For that reason I trust that anyone who contributed in the collection of data for the book will lay it to the loss of notes and not to the lack of appreciation, if suitable acknowledgment is not made herein by name.

Throughout the preparation of this text I have traveled in every sort of train and motor, with circuses, track-laying trains, and on private inspection trains; I have slept in grading camps, in cabooses of freight trains; and everywhere I have encountered the greatest courtesy and willingness to furnish information, and I desire here to express my appreciation of the kindness and assistance received from every source.

Corrections and criticisms of the form and subject matter will be gladly received.

WM. D. CONNOR,
Major, Corps of Engineers, U. S. A.

WASHINGTON BARRACKS, D. C.,
April 23, 1910.

PREFACE.

The book is intended for the use of those who are engaged in the service of railways, or who are about to follow that profession. It is a compilation of all matters pertaining to the subject, and does not pretend to be an exhaustive treatise on railway engineering, but it does give, in many instances, the experience and opinions of those who have had much to do with the results of practical railway engineering.

My two great sources of information in the preparation of this work are, I believe, unsurpassed in their respective fields in railway management, and whatever of merit may be found in this manual is largely due to them. To the civil side I owe much to Mr. H. A. Cushing, general manager of the Chicago and Northwestern Railway, through whose influence I was given every opportunity to secure information, and the methods in use on that railway. On the mechanical side I have to acknowledge the assistance of Sir E. B. Greenwood, K. C. M. G., whose thirty years' experience in the service of the Grand Trunk Railway, and its predecessor, the Great Western Railway, of which he was for many years the chief officer, and such a high authority on the subject, has enabled me to secure information required in most and some railway questions in the mechanical division. Things, however, have given solution of many points as regard the mechanical side of railway operation, which I hope may become to be learned from the history of the mighty railway of our neighbors.

I wish to express my appreciation of the assistance rendered me by the officials of the Chicago and Northwestern Railway, and especially to Messrs. Jones, of the Iowa Division, without a knowledge of the Lake Shore and Michigan Southern, Pittsburg and the New York Central and Hudson River Railroad I am indebted for information, and also for the use of many points on which I was not well informed, and also to the Chicago and Northwestern Railway.

In the preparation of all the subject matter on electrical construction, I have, and for Tables IX., XIX., and XX. I am indebted to the following: Prof. Wm. H. Searles, C. E., Mem. Am. Soc. C. E., whose field experience is one of the greatest assistance in the preparation of diagrams and formulæ relating to electrical construction.

To Mr. W. L. Webb, C. E., Mem. Am. Soc. C. E., I am indebted for Table XI and for many valuable suggestions during the work. Mr. Webb is the head of the Electrical Construction Notes on Track, by Mr. W. M. Camp, C. E., Mem. Am. Soc. C. E., has been invaluable to me both by suggestion of details and was most especially on the subject of rerail track laying and yards.

Table X is from the Mechanical Tables of Geo. H. Barlow, F. R. S. Tables XXI and XXII, from the Surveying, by Mr. J. Bourne, M. R. C. E., both of whom kindly gave permission to use their tables.

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International Reports, Royal Engineers.

Illustrated Annual, C. Spons and Chas. E. Brighton, Corps of Engineers, assisted me in revising the manuscript.

The text of this subject was written in 1905 and was then laid aside for four years. All notes were not collected and therefore I am unable to mention the sources of much of my information. For those I have forgotten I wish that anyone who contributed in the collection of data for the book will let it be the best note and not to the lack of appreciation, if suitable acknowledgment is not made herein by name.

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WM. D. CONNOR.

WASHINGTON BUILDING, D. C.,
April 22, 1910.

Major, Corps of Engineers, U. S. A.

MILITARY RAILWAYS.

1. Railways, constructed and operated for military purposes, vary from a rough, narrow-gage road on which the motive power is man or mule, to a fully equipped, modern, standard-gage road. The first would probably be used in the approaches of siegeworks and the latter when an existing commercial line was taken over for military uses. Between these two extremes are many grades of railways, but each grade shades imperceptibly into the next above and below, and any considerable classification must be artificial and of little use in discussing the general subject. The only classification that seems logical is to divide them into those that are built and operated within the field of the enemy's observation and those built and operated beyond his field of observation. The former are called **siege railways** and the latter **supply railways.** Supply railways and permanent railways differ only in the degree of care taken in their construction, maintenance, and operation. The same general rules govern both, and the engineer officer must apply those rules to suit the requirements of his particular case.

2. **Siege railways.**—Siege railways are those roads that are laid within the field of observation of a besieged place. The various lines that may be laid from a permanent railway line to the main camps, parks, depots, or other points outside of the field of observation are later discussed under the head of "Supply railways."

3. **Requirements.**—Siege railways must be capable of transporting guns, ammunition, and other supplies, especially those of the heavier kinds, to the various siege batteries, magazines, and bombproofs, and, possibly, to the various parallels that are constructed in carrying on the siege. From the nature of the line, it must be one that can be rapidly laid and as rapidly taken up and relaid elsewhere; it must not occupy too much space in the approaches and parallels; it must be of light weight, and it must permit of very sharp curves. The loads will be hauled either by men, by animals, or by a gasoline motor, as a steam locomotive would indicate too clearly its position by its smoke. These various requirements, therefore, demand a light, narrow-gage railway. If the grades will permit, a **gasoline motor** (fig. 1) may be made use of. These motors are made from 2 ft. to 4 ft. 8½ ins. in gage, and one weighing 2 tons will haul 10 tons on a level track.

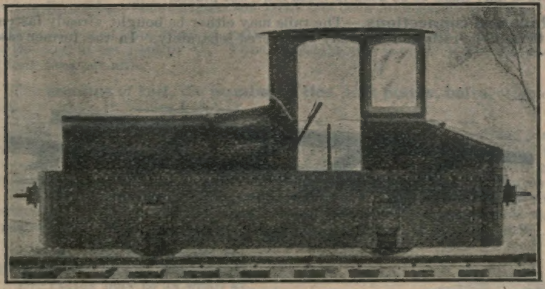


FIG. 1.—GASOLINE MOTOR.

The above engine is designed to meet a frequent demand for a gasoline locomotive for hauling various styles and weights of trailers, in mine quarry, elevator, and industrial works.

SPECIFICATIONS.—Motor, vertical type, ample power for service conditions; gage, 24 to 56½ inches; speed about 15 miles per hour; material, metal throughout, heavy railroad construction giving ample tractive power; cab removable for mine work; control, two speeds forward and same in reverse; height of drawbars to suit requirements; exhaust screened; brakes, standard type, applied to all four wheels.

4. **Alignment and grade.**—Within the field of observation of a besieged place, practically all movement must be made under artificial cover. The location of these lines of approach will be dictated by military principles, and the line of the siege railway will therefore be determined not by questions of economy or ease of construction, but by the location of the siege approaches and parallels.

For the same reason, the grade of the line is practically thrown out of the consideration, although a slight change in the direction of the approach might be made to keep the grade of the line below the limiting grade, if by such a change no military advantage were lost. This limiting grade should be kept as low as practicable, for the difficulties of moving cars under such adverse conditions are great at best, and for any slope greater than 6 or 8 ft. in a hundred the difficulties of ascent with loaded cars will be very great, even for animal traction; and above that, the cars would probably have to be moved by cable.

TRACK.

5. **Gage.**—The gage of the railway may be determined by any of several things. First, it may be desirable to have the gage the same as that of the supply railway beyond the field of the enemy's observation. Second, the nature of the ground through which the approaches pass may be such that an extremely narrow gage will be necessary. Third, the amount of narrow-gage railway stock and equipment that is kept on hand by the commercial firms of this country is very limited, and for a sudden call the choice of gages would not be very great. This last condition will probably be the controlling one, as at present there is no military railway equipment for our army. A **2 ft. 6 in. gage** railroad would answer the purpose as well as, or better than, any other. This is likewise a most desirable gage for a supply railway, and if notice can be had long enough in advance, the entire equipment for field railways might well be of this gage. Where the demand is immediate, correspondence with railway-equipment firms will inform the engineer of the gage of the track that they can most readily furnish and equip with rolling stock.

6. **Roadbed.**—There will probably be no time for ballasting the roadbed, and for this reason the ties used should extend well beyond the rails and, in order to form the least obstruction in the approaches, should be as thin as practicable (see par. 35). The trench will probably be drained to the rear, and the track should drain that way and not form an obstruction to the drainage of the trench. Sand, gravel, or fascines may have to be used to cross low, wet places.

7. **Rails and connections.**—The rails may either be bought already fastened to metal ties, or the rails and ties may be ordered separately. In the former case, the

FIG. 2.—PORTABLE RAIL SECTION.

sections are known as **portable tracks,** and usually come in 15-ft. sections (see fig. 2). The weight of the rail of such portable track is usually about 12 to 16 lbs. per yard, and the most common gages are 20 and 24 ins. Portable track of wider gage and heavier rails can be had by special order. The ties used are usually of the cross section shown in fig. 3, and standard sizes weigh 7 and 12 lbs. per yard. The rail is the standard T rail. The **connections** between the rails are usually the ordinary fish plates and bolts, as shown in fig. 3. **Angle bars** may be used if obtainable, though for so light a rail the **fish plate** answers every purpose.

8. The rails are fastened to metal ties with clips and bolts, as shown in fig. 4. If laid on wooden ties, the ordinary railroad spike will usually be used. However,

circumstances may demand that the railroad be laid without noise, in which case **lag bolts** can be used instead of spikes (fig. 5). A wrench for lag bolts is shown in fig. 6.

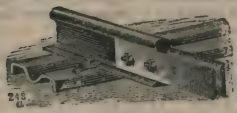


FIG. 3.—METAL TIE AND RAIL CONNECTIONS.

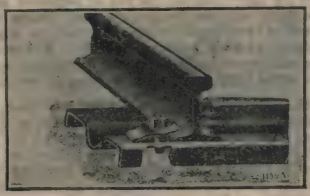


FIG. 4.—RAIL FASTENING TO TIE.

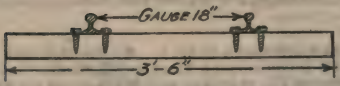


FIG. 5.

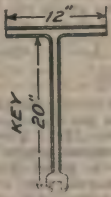


FIG. 6.

9. On tracks of this sort, with a poor roadbed, it is advisable to have the rail joints opposite each other (**square**), except on curves, where it is impossible to do this without cutting the rails. The joints of the rails should lie midway between two ties which are so placed that they rest under the opposite ends of the fish plates connecting the rails. This **suspended joint** has been found very satisfactory.

10. The number of long **tons of rail per mile** of single track is found by multiplying the weight per yard by $\frac{11}{7}$. Thus, for 35 lbs. per yard, $\frac{11}{7} \times 35 = 55$, the number of long tons per mile.

11. The **amount** of **rail,** the **number** of **ties, fish plates, bolts,** etc., per mile of track are shown in Tables I to VII.

12. **Table VIII** shows the weights, dimensions, and strength of rails of standard sections, and from this table the necessary weight of a rail can be ascertained for the load to be carried. A commercial portable track with a fair roadbed will carry a load in tons of about one-fourth the weight of the rail per yard, on a four-wheeled truck of commercial pattern. (This is approximate.) On a standard-gage road the locomotive should weigh, in tons, about what a yard of rail weighs in pounds. The **axle loads** of the loaded cars ought to equal the axle loads of the locomotive.

13. **Curves.**—The curves used on this kind of line usually have small radii. The radius may be as small as 12 ft., although a radius of less than 30 ft. is not advisable, if avoidable. For curves with radii over 500 ft., see par. 74 et seq. Curves with radii under 500 ft. can be laid off without the use of surveying instruments about as easily as with the use of instruments. For the portable track mentioned in par. 7, sections will be bent by the manufacturer to any desired radius (fig. 7). For other track, the rails must be bent and the center line of the track located in order to lay out the curve.

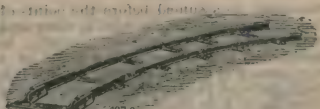


FIG. 7—CURVED RAIL SECTION.

14. A line of railway is made up of curved and straight lengths; the former are called **curves** and the latter **tangents.** Railroad curves are usually arcs of circles. They may be either simple, compound, or reverse. A **simple curve** is a curve with a constant radius of curvature. A **compound curve** is one composed of two or more simple curves of different radii curving in the same direction and having a common tangent at their point of meeting. A **reverse curve** is composed of two simple curves curving in opposite directions and having a common tangent at their point of meeting. The name is also commonly applied to two simple curves curving in opposite directions, which are joined by a tangent shorter than the usual length of trains running on the line.

15. A curve with a radius of less than 500 ft. is commonly referred to by its radius; as, a curve with 150 ft. radius, or a 150-ft. curve. Curves with radii longer than 500 ft. are usually designated by the number of degrees of arc that a chord 100 ft. in length subtends from the center of the circle. Thus, a 5° curve means that a 100-ft. chord subtends an angle of five degrees (5°) from the center of the circle. There are other means used to designate curves of very short radii, but they are more or less misleading; as, for instance, 8°_{25}, which signifies that a chord of 25 ft. on the circumference subtends an angle of 8° at the center. A **curve is measured** along its chords, and such length of chord should be assumed that the ratio of the arc to the corresponding chord is practically unity. The number of subtending chords multiplied by the length of such chords equals the length of the curve L. $L = \frac{\triangle}{D} l$, where $\triangle$ = central angle, D = degree of curvature, l = length of chords used.

16. The various **parts of a curve** are shown in fig. 8. We are supposed to be moving in the direction FBH. FB is one tangent joined to BH, another tangent, by the curve ADC. The angle between FB, extended, and BH is called the **external,** or **central, angle** ($\triangle$). B is the **point of intersection,** usually designated P.I. A is the **point of curve** (P.C.). C is the **point of tangent** (P.T.). O is the center of the arc. AC is the **long chord** (C), ED is the **middle ordinate** (M), and DB is the **external distance** (E). AB and BC are called the **tangent distances** (T). AO is the **radius** (R). The **degree of curvature** is D.

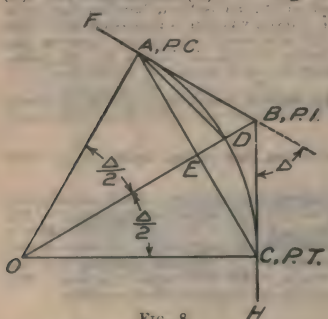


FIG. 8.

The relations between the various angles and lines can be seen from the figure. Various formulæ showing the relation of the different parts to one another are given in Table IX.

17. **Method of laying out curves.**—These methods vary greatly, and each depends largely upon the local accidents of the terrain. A few of the simplest are given here. In running a tangent along the line FB (fig. 8), the point B is reached where the direction of the line changes to BH. The exterior angle $\triangle$ is measured, and it is desired to put in a curve connecting the tangent FB with the tangent BH. Either the radius or the degree of curvature must be assumed before the points of tangency can be located. If the ground inclosed in the triangle ABC is clear and open, practically any curve can be run between the two tangents. Usually, however, there is some condition that determines where the curve shall lie and consequently what the radius of curvature will be. A common condition is that the point D in the curve must lie in the bottom of the trench; therefore, the distance BD must be equal to the distance from the P. I. to the bottom of the trench. A reference to Table IX will show the relation of the line BD (usually referred to as E) to the other parts of the diagram, and from this table, knowing the external angle $\triangle$, and measuring E, R can be determined. $R = \frac{E}{\text{ex. sec. } \frac{1}{2}\triangle}$

Given R, the distance AB and BC can be determined, since $T = R \tan \frac{1}{2} \Delta$.

In many cases an **auxiliary trench** will be necessary for the curve (fig. 8a).

18. Another condition that may arise is that there are on hand curved rail sections that must be used. From the above formula, knowing R, we see that $E = R \text{ ex. sec. } \frac{1}{2} \Delta$. This gives the value of E, and the trench must be widened so that the distance from the P. I. to the bottom of the trench is equal to E, plus the necessary width to give clearance for the cars. An auxiliary trench may be necessary for the curve (fig. 8a). T is determined as before. The curve can then be laid out by any one of the following methods that may happen to apply to the case in hand.

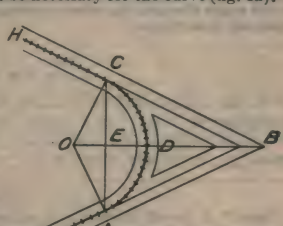


FIG. 8A.

19. **The method of offsets from tangents** (see fig. 9).—Knowing the P. C., P.T., and R, make a table for tangent distances and offsets. The distances on the tangent A*y* from the P. C. to the perpendicular offset from the extremity of any arc, A*a*, is equal to R sin D for the first station and R sin (*n* D) for any succeeding station (*n* being the number of the station from the P. C.); and any offset, as *ya*, from the tangent to the extremity of any arc is equal to R vers (*n* D). Having the tangent distances corresponding to the consecutive chords for half of the curve and the offset for each, measure off the distances from the P. C. along the tangent and locate each by a peg; then at each peg lay off perpendicular to the tangent the corresponding offset from the column of offsets. This locates half of the curve. Go to the P. T. and locate the other half of the curve from that point.

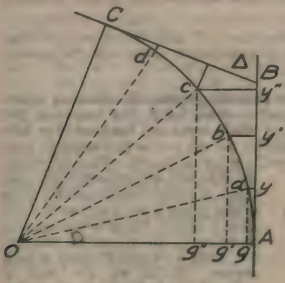


FIG. 9.

20. A **simpler form** of this same method by offsets from the tangents will be found by using Table XIII. This table gives the perpendicular offset for a curve with a 1-ft. radius at points one-tenth of the radius apart, measured along the tangent from the P. C. It will readily be seen that for any other radius the table will apply if every figure in the table is multiplied by the radius of the desired curve.

TABLE XIII.—Table of offsets from tangent for radius of 1 ft.

Radius	.1	.2	.3	.4	.5	.6	.7	.8	.9
1.00	0.0050	0.0202	0.0461	0.0835	0.1340	0.200	0.2859	0.400	0.5641

Method of use.—Having given the radius of desired curve, multiply each number in the table by its radius in feet and make a new table similar to the above. The figures in the lower line are then the perpendicular offsets from the tangent to the curve at points along the tangent whose distances from the P. C. are shown in the upper line.

21. **Example 1.**—Find the distances and offsets necessary to lay off a curve whose radius is 87 ft., P. T. and P. C. being known.

Solution.—Make a two-space table as below and in Table XIII, multiply the distances on the tangent and the corresponding offsets each by 87, and enter the distances in the upper line and the offset corresponding to each in the lower line. The table resulting is as follows:

TABLE FOR RADIUS OF 87 FT.

Distances ft.	8.7	17.4	26.1	34.8	43.5	52.2	60.9	69.6	78.3
Offsets ft.	0.435	1.757	4.010	7.265	11.658	17.400	24.873	34.800	49.077

From P. C. lay off the distances shown in the upper line along the tangent and at each point drive a peg; then from each peg lay off the corresponding offset perpendicular to the tangent. These points will lie in the desired curve. Use only as many points thus located as the central angle requires. If Δ is greater than 90°, locate the remainder of the curve from the P. T.

22. **Example 2.**—Having located P. C. and P. T., it is desired to lay off a 6° curve. The radius of a 1° curve is 5,730 ft.; therefore the radius of a 6° curve is $\frac{5730}{6}$, or 955 ft. Having found the radius, then proceed as above. This method of finding R is only approximately true. For a 20° curve the error is 0.5% and increases with the degree of curvature.

In many cases laying out half the curve from the P. C. and the other half from the P. T. will give the best results, since the perpendicular offsets will be shorter than when all points are located from one end.

23. **To locate a curve by offsets from the chords produced.**—Having determined R, assume some length of chord, C′, equal to about 0.2 R, but less than 100 ft., and from Table XIV find the corresponding offset from the tangent t for this length of chord. From the P. C. as a center, strike an arc across the tangent produced, using for a radius a chain whose length is C′, or Aa in fig. 10. Find the point on this arc a perpendicular distance, t, from the tangent. This is the point a on the curve. As shown in fig. 10, produce Aa, the distance C′ to b', strike the arc $b'b$, with a radius C′ from a as a center. Strike an arc with a radius $b'b = 2t$ from b' as a center. The intersection of these two arcs is b, a new point in the curve. Produce ab, a distance C′, to c' and strike the arc $c'c$, with C′ as a radius and b as a center. From c', with $2t$ as a radius, strike an arc, and where it intersects the previous arc is c, a new point in the curve. Proceed in a similar manner until a point is reached where the distance to P. T. is less than C′, the chord distance used. Measure the distance from the last station to the P. T. Call this distance x. Produce the last chord, the distance x to e', and strike an arc $e'e$, with x as a radius and d as a center. From e', with a radius equal to $\frac{2x^2}{C'^2}t$, strike an arc, and the intersection of these two arcs is e and should coincide with the P. T. This checks the accuracy of the work.

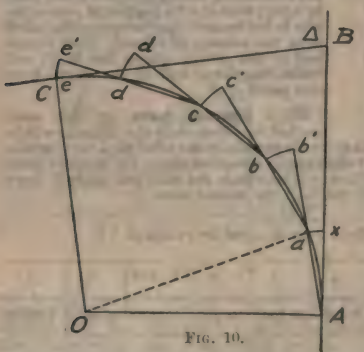


FIG. 10.

TABLE XIV.—Table showing tangent distances and offsets therefrom for certain lengths of chord in a curve of 1′ 0″ radius. All measurements are in decimal parts of the radius.

Length of chord	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Offset	0.005	0.020	0.045	0.080	0.125	0.180	0.245	0.320	0.405	0.50
Tangent distance	0.100	0.199	0.2969	0.3912	0.4841	0.5724	0.6557	0.7332	0.8037	0.8660

In fig. 10 the angles aAx and $\frac{aoA}{2}$ are equal.

Therefore, $ax : aA :: \frac{aA}{2} : ao$

$$\text{and } ax = \frac{aA^2}{2ao} = \frac{C'^2}{2R} = t.$$

24. **To locate a curve by middle ordinates.**—P. C., P. T., and R being known, assume some short chord, C′, whose ratio to the corresponding arc is practically unity. From $\sin \frac{1}{2} D' = C' / 2R$, find D′, the angle that this chord subtends for the given radius. Then $\frac{\triangle}{D'} = N$, the number of such chords in the curve to be laid out.

Lay off from P. C. toward center the distance Ag (fig. 11), equal to offset t, corresponding to C′, taken from Table XIV. Through g extend the line ga parallel to the tangent AB, and with the P. C. as a center strike an arc with a radius C′. The intersection of these two lines is a point in the curve, a.

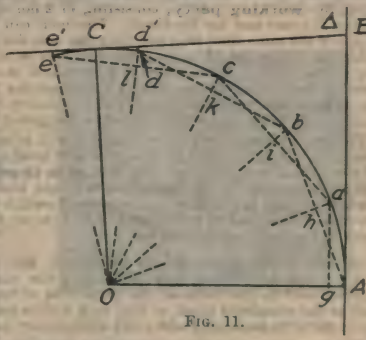


FIG. 11.

From a lay off a distance in the direction of the center, ah, equal to t. Extend the line Ah, and with a as a center strike an arc with C′ as a radius. The intersection of Ah with this arc is at b, another point in the curve.

If N is a whole number, the P. T. will be one of the points found as above. If N is not a whole number, lay off the whole-numbered stations as above until a station, e, is located, just beyond the P. T. Measure Cd and Ce. From Table XIV find the offset corresponding to each of these chords. From d and e lay off dd' and ee' perpendicular to the direction of the new tangent. The line $d'e'$ should coincide with the new tangent and pass through C

25. There is another method of laying off curves without the use of instruments, i. e., by **offsets from the long chord** of the curve, but it is not believed that this method would be of any practical value in the field; and if occasion arises where its use is necessary, the engineer can readily figure out the method for himself.

The foregoing methods will not always locate points on the curve a fixed distance apart, but as rapidity of location is desired rather than careful notes for future record, the preceding methods are well suited to the case of siege railways.

26. The angles made in the trench lines of siegeworks are so sharp that curves with very short radii will be necessary. Sharp curves, even with low speed, mean derailments and the consequent trouble; and the use of "**switchbacks**" is recommended when the question of speed is a minor one, as i usually is on a siege line.

ABC (fig. 11a) is the change of direction of an approach; the angle is not exaggerated. A very sharp curve would be necessary to get from A to C by an auxiliary trench, F, par. 17. A much better method is to extend the trench from B to D and lay the track to D. At B a switch is put in and the line continued to C. BD must be longer than the probable train length and level if possible. The train is moved onto BD, and the animals are put on the other end of the train, or the motor is run backward and the train proceeds, via BC, to the next switchback, when the operation is repeated. E makes an excellent place for storage of tools or materials, or for a dressing station.

FIG. 11A.—SWITCHBACK.

27. **Track centers.**—Having decided upon the track to be laid, the **center line** is marked by center stakes about 100 ft. apart, on tangents, and as near together on curves as the radius of curvature requires.

28. **Track laying.**—In laying a portable railway, all sections of the track should be inspected before they are sent to the railhead, to make sure that the ties are properly bolted to the track and that the necessary fish plates are attached to one end of each section. The sections are then loaded on the cars with all fish plates pointing toward the head of the track, and the cars are hauled out to the railhead. At this point the **working party,** consisting of 2 noncommissioned officers and 24 men, unload the cars and lay the track. Two men can unload and lay a section of track in about the same time that two men can bolt the fish plates. The party can be divided into two parts, 12 men carrying the rail sections and 12 men bolting and fastening up the joints. The cars are so light that if there is room in the trench the head cars can be lifted off the track and the remaining loaded cars run past, after which the empties can be puton the track and hauled to the rear. They will either be run singly or in trains, according to the tractive power that is used.

The track-laying party should be followed by another party, consisting of 1 noncommissioned officer and 24 men, who will level up the track, align it, and see that all ties have a good bearing. The **officer in charge** at the rear should inform himself in advance of the location, number, and kind of curved sections that will be needed, and also the location and number of switch sections, and should see that these are sent to the front in their proper order, so as to come to hand for the working party at the point where they are needed.

29. For laying siege railways on wooden ties, the rails must be loaded on the cars nearest the railhead and the ties on the cars to the rear. In every train of material sent to the railhead, the proportion of ties and rails will be that of ties and rails in the completed track, so that both will be used up at the same time and allow the train to return empty and avoid unnecessary hauling of material.

The tie gang carries the ties ahead and drops them in position. One man is charged with giving ties their correct spacing and alignment; two men at the rail car fasten the fish plates to the forward end of the rail, if this has not already been done at the rear, and the rail is carried up and laid with its end between the fish plates at the head of the last preceding rail. The fish plates are bolted temporarily with one bolt, and a clip and rod (**bridle,** fig. 77) fastens the rail bases together temporarily. The construction train is then pushed ahead toward the end of the rail just laid and there halted until the next rail is laid.

Behind the train is the bolting party that bolts the fish plates permanently to the rail, the spiking party that spikes or screws the rail to the ties, and the surfacing party that aligns and surfaces the track. This is an adaptation of the method described in pars. 145 to 154.

30. All the **working parties** on this work should be under an officer who has an assistant at the rear charged with getting out and forwarding all material needed.

This last officer's instructions should be such that he clearly understands what material is wanted, and when and where it is wanted. All **rail cutting** should be done at the rear.

It may be feasible to spike the rails to the ties and bolt on the fish plates in the rear, in which case the line is laid as described for portable track. This method would not be economical of space in loading.

31. **Curving rails.**—Before any rail is spiked to its place in a curve it must be evenly bent from end to end, so that it will assume the proper curvature when lying free. This curving may be done by hammers, but that method is slow, and a **rail-curving machine,** shown in fig. 12, is more commonly used. Two forms of **rail bender** are shown in figs. 13 and 13a. These are made with either screw or hydraulic power, and are used for bending rails rather than for curving them. For many curves no rail curving is necessary, the friction between the rail and the ties being sufficient to hold the rail in position. The extent of this flexibility depends on the weight and length of the rail, and can be found by trial; 3° and sharper curves usually require a curving of rails.

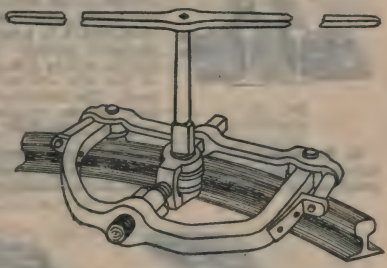


FIG. 12.—RAIL-CURVING MACHINE.

FIG. 13.—JIM CROW RAIL BENDER.

FIG. 13A.—Q. & C. RAIL BENDER.

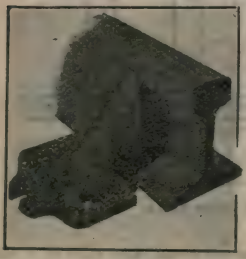


FIG. 14.—RAIL BRACE.

32. Knowing the radius of the curve and the length of the rail, the **middle ordinate** of the rail can be taken from Table XV. Each half of the rail, from the middle point to the ends, should also be tested for its middle ordinate to insure uniform curvature. The middle ordinate of these half sections is one-fourth of the middle ordinate of the entire rail.

33. **Rail braces.**—The **outer rails** of very sharp curves are frequently braced with braces of a kind illustrated in figs. 14 and 116. An angle bar nailed to the tie and butting against the web of the rail furnishes a very good brace. (For elevation of outer rails of curves, see pars. 81, 82.)

34. On **very sharp curves** it is a good precaution to have the inner line of track doubled by the use of a **guard rail,** as shown in fig. 15. This will frequently prevent derailments and the consequent delay and trouble.

FIG. 15.

35. **Ties.**—In case **metal ties** can be obtained, and the necessary punch for punching the bolt holes is at hand, these ties are preferable to wooden ones on account of the smaller space they occupy. For track laid on the ground **without ballast,** the ties should be at least 2 ft. longer than the gage of the track, to give good bearing. In case **wooden ties** are used, 3 by 6 in. or 3 by 9 in. ties are probably the best. If ties of this size are not at hand, thicker ones may be used. The distance between the ties depends upon the load and the weight of the rail. (For strength of rails, see Table VIII.)

36. **Switches.**—For a portable railway, **switch sections** are made that include the main track and turnout from the point of switch to beyond the frog. These switches are usually split switches, as illustrated in figs. 16, 17, 18, and can be purchased for either right or left hand single switches, two-way or symmetrical switches, or three-way switches. If purchased in this shape, they can be laid down in the track at any point by taking up a section of the same length and substituting the switch section. The radius of the standard curve of departure for these switches is 30 ft.

FIG. 16.

FIG. 17.

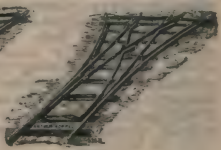


FIG. 18.

PORTABLE SWITCHES.

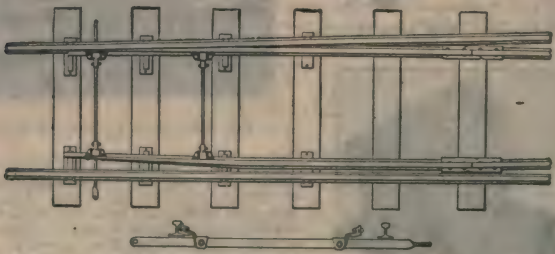


FIG. 19.—SPLIT SWITCH FOR LIGHT RAILS.

The **commonest gages** carried in stock are 20 and 24 ins., with 12 or 16 lb. rails. The switch sections usually correspond in length to the sections of straight track made by the same manufacturer. On short notice, these firms will build switch sections of any particular kind, gage, or weight of rail.

The **parts of a switch** (figs. 19, 20, 21) are as follows:

One pair switch points, with slide plates.
The necessary connecting rods.
One ground throw or stand.
One frog.
One pair guard rails (figs. 96, 98).

FIG. 20.—GROUND THROW SWITCH.

For the method of **putting in switches** for other than portable track, see par. 157 et seq. In cases where the point of connection changes frequently, on light track, an **inclined switch**, as illustrated in fig. 22, may be used. This can be laid on a track at any point, and has been used on standard-gage roads for temporary sidings.

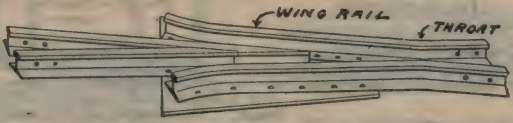


FIG. 21.—PLATE FROG FOR LIGHT RAILS.

37. **Stub switches.**—It may happen that there are frogs on hand, but no split switches. In this case what is known as a stub switch (fig. 23) answers every pur-

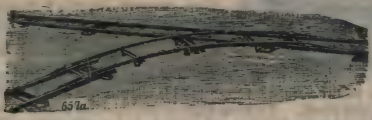


FIG. 22.—INCLINED SWITCH.

pose for a siege railway. The frog is located and the rails of the turnout and main track are laid on their regular curves until the distance between the heads of the

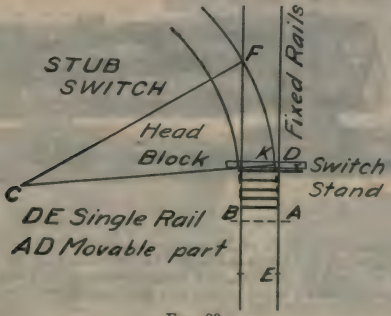


FIG. 23.

rails is equal to the required clearance for the wheel flanges. These rails are all permanently fastened and the adjacent half of the rail on the main line is left movable, leading either to the turnout or continuing on the main line, according to the

way it is set. The movable parts of these rails are connected by switch rods and slide on metal plates. (See par. 190 for fuller description.)

FIG. 24.—CROSSING.

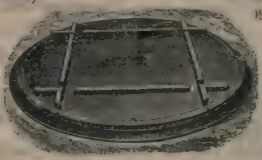


FIG. 25.—TURNTABLE AND CROSSING.

38. **Crossings.**—For stock gages, right-angle crossings are usually kept in stock by the manufacturers (fig. 24). Crossings for any angle and weight of rail can be made on short notice. In ordering state the crossing angle and the degree of curvature, the gage, and weight of rail of **each track.** The **angle of crossing** of two curves, or of a curve and a tangent, is measured by the angle between the tangents at the point of intersection. The angle at each rail crossing can be computed in the shop. Where two roads must cross and no crossing is at hand, one track can be raised a sufficient amount to allow a movable section of rail to be put into place across the other track. When the cars have passed, the section is taken out opening the lower track to cars.

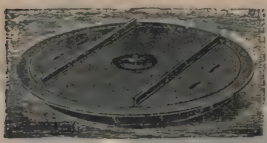


FIG. 26.—TURNTABLE.

39. **Crossings for vehicles** are made by nailing planks to the ties, or to blocks laid in the bed of the track. To keep such crossings clean and thereby prevent cars from jumping off the track, it is a good plan to lay a rail on its side along the inside of each rail of the track, the head of such rail to lie against the web of the track rail.

40. **Turntables.**—For sharp turns, and for turning cars and locomotives, turntables are necessary. The commonest kinds used with portable track are shown in figs. 25, 26. These are furnished ready-made by the railway-equipment firms. (For a complete turntable see par. 199, fig. 110.)

FIG. 27.

41. **Cars.**—Commercial types of narrow-gage cars are made entirely of steel, entirely of wood, or of the two combined. For certain uses the all-steel cars are very good; but for work in the field, cars with wooden bodies have been found to be much easier to repair, and a break of any sort does not throw the car out of use for a long time.

All cars should have the **coupling bars** the same height above the rail. They should have **rings** or **hooks** on each corner, by means of which they can be moved by animals walking on the *side* of the track. As far as possible all parts should be interchangeable.

Some types of cars are shown in figs. 27 to 34.

Fig. 28 shows a type of small, heavy, **platform car,** with removable walls, specially adapted for shells, bombs, or similar articles, 20 to 24 in. gage, about 3 ft. by 2 ft. 6 ins.

Fig. 29 is a small **platform car,** with steel frame, platform of steel, of wood, or of wood lined with steel, for hand power, capacity from 2 to 3 tons, 18, 20, or 24 in. gage, size of platform about 3 by 5 ft. Other sizes made to order.

FIG. 28.

FIG. 29.

FIG. 30.

Fig. 30 shows a light push or **hand car,** made any size of gage.

FIG. 31.

Fig. 31 shows a wooden **flat car,** capacity 10 to 12 tons, 20 to 28 ft. long, 5 to 7 ft. wide, narrow gage.

Fig. 32 is an eight-wheeled **gondola car** with steel frame, pressed trucks, capacity from 7 to 10 tons, for narrow gage.

Fig. 33 is a car for carrying sick and wounded, 24 in. gage, about 15 ft. long and 5 ft. wide.

Fig. 34 is a small all-steel truck, with or without brakes, of about 2 tons capacity, generally furnished for 24-in. gage.

FIG. 32.—GONDOLA.

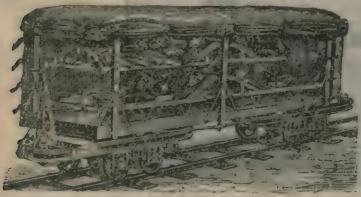


FIG. 33.—CAR FOR WOUNDED.

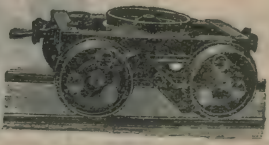


FIG. 34.

The trucks in figs. 27 and 33 are identical and show how narrow-gage equipment can be converted from one use to another.

42. By constructing a wooden top frame, trucks similar to fig. 34 can be utilized in pairs for **transporting siege guns** and other heavy armament. In case there

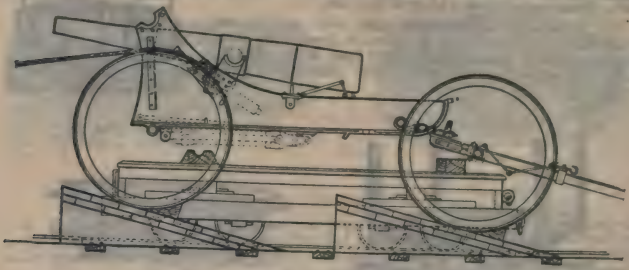


FIG. 35.—LOADING A SIEGE GUN ON TRUCK.

are steep grades, a truck similar to this is built with a brake. The method of mounting the armament on such a truck is illustrated in figs. 35 and 35a.

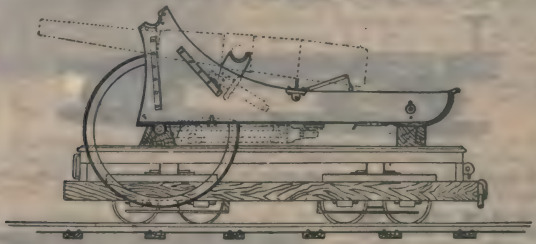


FIG. 35A.—SIEGE GUN LOADED.

The track is floored over for a sufficient distance to allow the gun to be run across the railway and moved so as to lie longitudinally along the track. By means of

FIG. 36.—FEWING'S CAR AND ENGINE REPLACER.

ropes, the gun and its limber are run up special ramps (outside of the rails) until they are higher than the body of the car; the wheels are then chocked and the car run under

the gun. The necessary blocking is put on the car and chocks are removed, whereupon the gun and limber roll down the ramps and the gun settles on the blocking. The limber is then released and the gun is ready for movement. The gun is unloaded with similar appliances. One limber is sent on the first car to be used in unloading the guns when they arrive.

43. **Tools and appliances.**—See par. 111 et seq.

44. **Derailments.**—Owing to the light weight of narrow-gage cars, an empty car can easily be lifted back on the track if it is derailed. With loaded cars, however, this is not always the case, and the use of **car replacers** (fig. 36, page 18), facilitates this replacing without unloading the cars. There are many kinds of car replacers. The one shown, Fewing's, is a good one for heavy cars and locomotives.

SUPPLY RAILWAYS.

45. Supply railways include all railways, except siege railways, that may be constructed or used for the supply of an army in the field. They may vary from a light portable track to a standard railway. Their **principal uses** will be, to connect the army with its base; to connect permanent camps with the nearest existing railway; to form a belt line around a besieged place outside the field of observation; to form a belt line inside the line of defense of a besieged place, for the movable gun defense, and for a general supply line; and to connect landing points with each other, and with an existing railway in operations over the sea. In extreme cases this supply railway may have to be constructed to supply an advancing army when local conditions preclude other means of transportation.

46. Regardless of the gage, the same underlying principles govern the construction of all such lines, and having a plan for the operation and maintenance of an existing line of railway, it is easy to adapt it to the requirements of a temporary line. The **principal considerations** in planning for such a line are, first, the amount of army supplies, troops, and animals that must be hauled; second, the time that can be permitted for its construction; and third, which applies particularly to operations beyond the sea, the amount of transportation to place the railway supplies on the work. The first two, taken in conjunction with the third, necessitate a narrow-gage railway for a supply railway in a country beyond the sea. Local conditions, such as a great supply of standard-gage material and rolling stock, may render advisable the building of a standard-gage railway for operations from a friendly land base; but where conditions extremely favorable to a standard-gage line do not exist, a narrow-gage railway will probably be decided upon in the general case of supply railways. The weight of the materials and rolling stock is so much smaller, the bridges can be so much lighter, and the earthwork is so much less than for a standard-gage road, that the narrow-gage railway is decidedly easier and quicker to build.

47. On the Barsi Railway, built in India, a 2 ft. 6 in. gage was used. The weight of the locomotives was 58,800 lbs. in working order. It had an eight-wheel base with a four-wheel pilot truck (bogie), 13 by 18 in. cylinders, and used a working steam pressure of 150 lbs. The rigid wheel base was 8 ft. 3 ins.; total wheel base, 18 ft. 6 ins. The weight on each of the six axles was 10,000 lbs. The sharpest curve on the line has a radius of 175 ft. On a level tangent this locomotive drew 1,036 tons at 15 miles an hour; and on a 1% grade, 9½° curve, it hauled 291 tons at 8 miles an hour.

They were able to run sixteen trains a day in each direction, which, excluding the weight of the cars, carried 3,360 tons each way daily. The load on each car axle was the same as on the locomotive axle, i. e., 5 tons. The weight of rail used was 35 lbs. per yard.

48. General Sherman's army at Atlanta was composed of 100,000 men and 35,000 horses, in a hostile country. The **train supply** to him was 1,600 tons daily, which he said was in excess of the amount necessary to supply his army. It will thus be seen that it is possible for a 2 ft. 6 in. gage railway to supply an army of about 200,000 men and the necessary animals, at a distance from the base dependent only upon the available amount of rolling stock and the location of necessary railway operating supplies. This, of course, is barring accidents and interruptions to traffic.

49. The **narrow-gage locomotives** built in this country give even better performances than that cited in par. 47 for an eight-wheel locomotive, 14 by 18 ins., Class D. T., built by the H. K. Porter Company, of Pittsburg, weighing in working order 60,000 lbs., is rated with a capacity of 1,875 tons on the level, 425 tons on a 1% grade, and 220 tons on a 2% grade; while Class D. T. locomotive, with 11 by 14 in. cylinders, weighing 36,000 lbs., is rated at 1,075 tons on the level, 240 tons on a 1% grade, and 120 tons on a 2% grade. The **axle load** in the first case is 7½ tons. The weight of rail necessary is 30 lbs. per yard. The axle load of the second locomotive is 4½ tons and only requires a 20-lb. rail.

The **rating** of these last two engines is based on the frictional resistance of 6⅔ lbs. per ton. This resistance may vary from 5 lbs. to 10 lbs. for good cars and track, and may run higher for poor cars and track (see pars. 20e, 207.)

50. The question of **time** not only enters into the question of construction of the road, but is also an important factor as to the amount and kind of narrow-gage rolling stock that can be furnished. For a **short line,** say 10 miles in length, it is probable that the equipment and rolling stock could all be bought from stock. This would mean adapting the grade and gage to the rolling stock, supplies, etc., that the manufacturers had on hand. For a narrow-gage line of **considerable length,** say 40 to 50 miles or more, it will be absolutely necessary to have considerable notice, and the same will be especially true if the material is to be transported across the sea. Under either circumstance, the engineer will first fully acquaint himself with all the plans of the G. C. and ascertain the general line over which the railway is to be built and the probable army that will have to be supplied. A study of the best maps available will then show him the general features of the country through which the line is to run. On over-sea expeditions the list of material may have to be made up from this imperfect knowledge of existing conditions.

If a very accurate and **detailed map** is at hand, the work will be simplified; if not, a general **reconnaissance** should be made of the ground to be covered, where such a thing is at all possible. The engineer will, meantime, enter into communication with the manufacturers of railway equipment of all kinds, and he should then be able to make a bill of material for the railroad that is to be built. If necessary, pressure should be brought to bear on the manufacturers to make them rush his order through without delay and in advance of all other similar civil orders.

SURVEYS.

51. **Routes.**—In some cases it will be possible to go over the route and locate the exact position of the whole railway before construction work commences, and in any case the general line of the road will be known although the exact location may not be determined except as the army advances. In either case, **surveying** will have to be done in order to determine the best line for the road and to locate this line on the ground. Whether this be done in peace or war makes no difference in the general principles, but the circumstances of each particular case will necessitate a judicious determination of the proper care and accuracy that must be used in that case.

52. **Survey.**—After a careful study of the best maps obtainable, the **preliminary survey** must be undertaken. The line will have been roughly located on the map so as to follow the most nearly level ground and to cross the fewest number of streams. The general location is usually determined by a horseback reconnaissance at least one day in advance of the transit party. The transit line is run over the indicated route and the distance is chained. If a good map is at hand, sufficient notes only are taken to locate the route on this map; otherwise fuller notes are taken so as to permit the making of a rough map. Grades are approximately measured by vertical angles, though an experienced locating engineer becomes very expert in judgment by eye alone. (Table XX.)

53. **Parties and instruments.**—The **transit party** is usually made up of the chief of party (who is the transit man), two chainmen, two flagmen, and a stake driver, and such laborers as may be needed to clear a line and remove obstacles.

54. The **level party** on the preliminary survey consists of an instrument man, one or two rodmen, and any laborers that may be needed to clear the line. This party, when staking out the actual line of the road, will consist of an instrument man, a rodman, and two helpers, one to help the rodman with the tape and one to drive stakes.

55. The **instruments** and **tools of the transit party** are one transit (about 5-in. plate), two flags or rods, a 100-ft. chain, a transit notebook, machetes and axes to suit the country, and a supply of small nails or tacks. One man in the party should have an engineer's pocketbook containing formulæ and tables. The kind and number of tools for the clearing laborers will depend on the character of growth to be cleared and the size of the gang.

56. The **instruments** of the **level party** are a "Y" level, a 100-ft. metallic tape, a level rod (Philadelphia), a level notebook, an ax, a machete, and clearing tools for the laborers. The party should have at headquarters, or should carry with the headquarters wagon, a drawing board, drawing paper, one box of drawing instruments, a box of railway curves, a circular protractor, scales, profile paper, and an engineer's handbook, together with the necessary supply of inks, pencils, etc. There should be a **camera** in the party that will take a picture about 5 by 7 ins., as frequently the situation at **bridge sites** can be more clearly shown by the aid of a picture than by any other method.

57. The **plane-table party** for the survey of special locations requires a plane table about 20 by 24 ins., two stadia rods, two machetes, and one handbook containing tables for reduction of stadia observations.

All parties should be supplied with timber crayon for marking stakes and noting elevations on same.

58. **The transit party** leaves plainly marked stakes along the center line which can be seen one from another, and gives the references to these points in the notebook. Note is also made of the class of the soil, outcroppings of rock, location of timber, etc.

59. The **level party** follows the transit party on the preliminary survey as soon as the line is indicated. A sufficient number of elevations of the ground are taken to indicate the changes in grade. Where the ground on both sides of the center line has the same elevation as the center line no side readings are taken; where the line runs along a sidehill, and wherever an unsymmetrical cut or fill appears necessary, readings will be taken for 200 to 400 ft. on each side of the line, at points such that the resulting notes will give a fair representation of the ground.

60. The **notebook** must be kept up, so that each time the instrument is moved the elevations up to that point have been computed.

61. Readings on the center line longer than 350 ft. should not be taken except for some special reason. The **foresights** and **backsights** of turning points should be equidistant from the instrument. **Bench marks** should be established not more than a mile apart, and each one should be distinctly marked and described.

62. **Cross sections** should also be taken on the inside of each deflection angle for use in the selection of the curve for that part of the line. At **crossings of streams** and gullies full notes should be taken, with a statement of the probable elevation, length, and kind of bridge to be used, together with full information as to the necessary foundations, the condition of the banks, the kind of bottom, the depth of water, rate of current, elevation of highest indications of high water, the nearest bridge materials, and a sketch or photograph and description of any existing bridge.

63. Before the survey is started, the **maximum grade and degree of curvature** should be decided upon, and in surveying the line the instrument men will know what their limitations are and will locate the line accordingly. This maximum grade should be the **compensated grade.** That is, when the grade occurs on a curve, an allowance of .04% of grade should be added to the actual grade for each degree of curvature to give the compensated grade. When the level man finds the grade running steeper than the limiting grade, he will take a sufficient amount of side notes to determine the **amount of excavation** or filling that will be necessary to keep the grade within the prescribed limits; and if he finds the amount of excavation excessive, he may have to call back the transit man and have the line relocated. This should not happen frequently, as the transit man should know the maximum allowable angle of slope and should locate his line accordingly.

The combination of notes of the transit and level parties will show the grades and the curves that will be necessary, and will thus determine the practicability of the route selected. Below the limiting grade that a lone locomotive can ascend, the

working maximum grade for the line will be different in every case and there is no such thing as a fixed maximum. The only general rule is to keep it as low as practicable and still keep the amount of construction work within reason. Par. 206 describes the method of finding the **tractive power** of a locomotive. Knowing the available rolling stock, the amount of supplies to be transported, and the nature of the country, the maximum grade will always be a compromise between what you can get and what you would like to have. Pars. 47 and 49 show that grades above 2% are almost prohibitive. The maximum degree of curvature is not so indefinite. There is a railway in Colorado with **50 curves of 20°**, or more, in 11 miles. The Baltimore and Ohio, until recently, had a **300-ft. curve** at Harper's Ferry on its main line. The 175-ft. curve (par. 47) on the Barsi road could undoubtedly be made sharper and still be practicable. With these as limits, a road can wind in and out through almost any country. Keep in mind that **sharp curves are preferable to steep grades** if it becomes a question between the two.

64. It is assumed herein that the officer in charge of the work is acquainted with the use of instruments, and so no explanation is made of the instruments nor of the methods of using them.

Upon the completion of the survey and the determination of a practical route will come the **location** of the **line of track.** This may either be done by the preparation of a map whereon are plotted the cross sections taken, or the profile may be plotted and any objectionable features, such as excessive grades, cuts or fills, can be corrected by the necessary deviation when the engineer reaches that point in the line in the course of the actual, final location. In the first case, the center line having been plotted, where no cross sections have been taken, it is assumed that the track may be moved 100 ft. in either direction without changing the elevation materially. Where the cross sections have been taken, the desirable center line is indicated by a series of points and the center line of the track is located to correspond approximately to these points. The line along the part not cross-sectioned is then shifted to one side or the other to correspond. Theoretically, this is the best way to locate a line of railroad; in practice, however, railroad locating engineers become expert in the location of lines on the ground, and due to inaccuracies which occur in all maps, it is usually found that the engineer will have to change the center line more or less, no matter how carefully it was located on the map.

65. A **profile** will be made showing the elevations of the center line finally decided upon, and by means of pins and threads the exact elevation and grade of the line can be determined for every station. In this determination the notes taken by the transit party regarding the class of soil, rock, etc., should be considered.

66. The foregoing description of the method of location sounds cumbersome, but the actual work can be kept up so that before going to bed at night the locating engineer has determined the line and grade of his track up to the end of the day's work, or else has determined that that particular line will not satisfy the limiting conditions of the case in hand. In either case, the next morning the party is prepared to continue work, or to start afresh at some point back on the line, knowing that the work up to the point of starting has thus far determined a satisfactory location for the line.

67. In a very **rough country** it may be found advisable to use a plane table in the construction of the map for determination of the route; the advantage of this method is that a map of a certain area can thus be obtained with a great deal less labor than by the use of the transit and level. The plane table is especially useful for mapping bridge sites, but for general location has not been found as practical as the method of transit and level.

68. **Instruments** should be checked as to their **adjustment** often enough to keep the instrument man confident of their approximate adjustment.

69. **Sidehill work.**—In locating the line on the side of a hill the center line should be run along the surface of the ground, if this can be done by a slight movement to one side or the other. This will equalize the necessary amount of cutting and filling, and will minimize the movement of material.

70. **Vertical curves.**—On a line with grades between 1% and 2%, vertical curves will be necessary where two sharp grades come together. They prevent trains from breaking in two, an accident that frequently happens when the forward part starts

downhill and the rear of the train is still on the upgrade. In fig. 37, AB is the upgrade and BC the downgrade. The stations indicated are 100-ft. stations. It is desired to run in a vertical curve on this hill and avoid the sharp change at B. Decide on the desired length of the vertical curve, and on the profile draw the chord

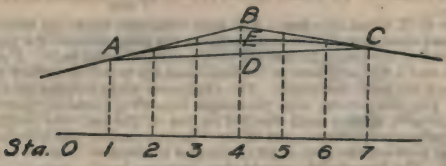


FIG. 37.—VERTICAL CURVE.

AC corresponding to this length. Half the difference between the elevation of B and D is approximately the middle ordinate of the curve, and locates the elevation of the curve at the point E. Then let M be the *correction* in elevation at the point B.

$$M = \frac{1}{2}\left(\frac{\text{elev. A} + \text{elev. C}}{2} - \text{elev. B}\right).$$

The correction for any other point of the vertical curve is proportional to the square of its distance from the nearest end of the curve divided by the square of the half length AB. The correction is negative when the curve is concave downward, and is positive when the curve is concave upward.

71. **Vertical curves** vary in length according to the sum of the adjacent grades. A rough rule may be given that the length of the vertical curve, L, equals the change of adjacent grades (in per cents) times 250 ft. The curve extends an equal distance on each side of the apex.

Example.—A +2% grade joins a −1.5% grade. How long should the vertical curve be? $(2 + 1.5)\ 250 = 875$ ft.; 437½ on each slope.

72. **Drains and culverts.**—The engineer should examine every depression crossed in the survey, and will decide whether or not water will accumulate behind the railroad bank if no culvert is put in. If there is a drainage area of any extent on the uphill side, a culvert or drain of some sort will be put through the embankment at this point to carry off the water. A blind drain will sometimes answer, but it is better to put in a box drain or leave an opening in the embankment and put in a small bridge. These drains should be perpendicular to the track. The area of the opening in square feet given by Myer's formula is:

$$A = C\sqrt{\text{drainage area in acres}}. \quad C = \begin{cases} 1, \text{ in flat country.} \\ 1\tfrac{1}{2}, \text{ in hilly country.} \\ 4, \text{ in rocky, mountainous country.} \end{cases}$$

73. **Tunnels.**—In a field line, a tunnel is practically an impossibility on account of the difficulties of construction and the time necessary to build one.

74. **Location.**—Having determined on the grades and the approximate location of the line, the next work is the actual location of the line on the ground. The stakes for the construction parties are set and all changes in location are made that are necessary to keep below the maximum grade or to avoid difficult construction. The transit line is run over and stations are marked every 100 ft. to indicate the center line. The only point of the transit work that needs mentioning is the **laying out of the curves.** The parts of a curve have been explained in par. 16. The method of determining the P. C. and P. T. has been explained in par. 17.

Arriving at the P. I., the exterior angle is measured, and knowing either the radius, or the degree of curvature desired, the other is determined as in par. 17. Having located the P. C., the transit is set up at this point and the zeros of the plate

and vernier are brought together and clamped in that position. The instrument is then sighted along the tangent produced and an angle is turned off toward the side to which the curve is going, equal to the chord distance to the next station divided by the distance between stations, and multiplied by one-half the degree of curvature. Thus the P. C is at station 10 + 40; the degree of curvature is 4° R; the length of stations used is 100 ft. To locate station 11 turn off $\frac{60}{100} \times 2°$, or 1° 12′, to the right and measure 60 ft. along this line. The rear chainman holds the 40-ft. point on the P. C.; the head chainman moves to the right of the tangent until the point of his flag, held at the end of the chain, is bisected by the vertical cross hair. A stake is driven at this point and a nail is driven in the stake and the point is verified by the instrument man and the head chainman. The chainmen move out and thereafter use the full chain. The instrument man thereafter lays off 2°, that is, half the degree of curvature, for each station until the last station in the curve is reached. He then lays off the proper proportional part of the deflection angle, which should be equal to the difference between the sum of all the angles theretofore laid off and half the external angle. The line of sight should then intersect the tangent at the P. T. if the work has been correctly done, and the **length of the curve** should be $100 \frac{\Delta}{D}$ ft. If either of these two conditions is not fulfilled on reaching the P. T., some mistake has been made and the work must be corrected. In turning off these angles as above, it is best to make out a table before starting that shows what the vernier should read at each point. This does away with the chance of a cumulative error that exists in turning off a small angle several times. Very sharp curves are usually led up to, from each end, by a compound curve, composed of several simple curves the radii of which decrease from that at the P. C. to that of the main curve a few hundred feet from the P. C.

75. **P. I. inaccessible.**—When the P. I. is inaccessible, it may be necessary to make several changes of direction, as in fig. 38. The point V would be the P. I., but it is inaccessible. The line is run along BQPA, PA being the desired direction of the

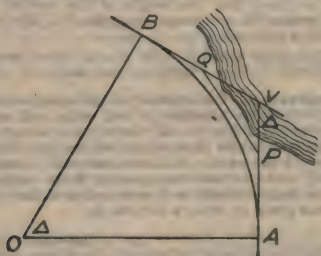


FIG. 38.

new tangent. The external angle is then equal to the sum of the deflection angles at Q and at P. In the triangle QPV, all the angles and the side PQ are known. Solve the triangle for QV and PV. Find the tangent distance VB and VA as in par. 17, and lay off from Q, QB equal to VB minus VQ; and from P, a distance equal to VA minus VP. The points B and A thus located are the P. C. and P. T., respectively. The curve is then laid out as heretofore described.

76. **A curve requiring more than one setting of the instrument.**—As errors will creep into the location of a curve if very long lines of sight are used in laying out the curve, it is customary not to lay out more than five or six stations from one point; therefore, on curves longer than this, two or more settings of the instrument will be necessary. This is also the case when the line of sight is interfered with by

some obstacle. Having located the curve as far as Q, in fig. 39, from the P. C., it is decided to use a new setting of the instrument. The instrument is moved to Q and set up over this station. The zeros having been brought together, a backsight is taken on the P. C., the telescope is plunged, and an angle is turned off to the inside of the curve equal to $\frac{D}{2}$ multiplied by the curve distance to Q, in feet, and divided by 100. This is equal to the angle VBQ. The instrument should now read the same angle that it did to locate Q, and the line of sight is tangent to the curve at this point. From Q the curve is continued in the same manner that it was from the P. C.

To be general; when the instrument is set up on any forward station of a curve, backsight to any previous station with the plates set at the originally computed deflection angle for the station sighted at. Plunge the telescope and set the plate at the angle of deflection originally computed for any forward station and the line of sight will point to that station.

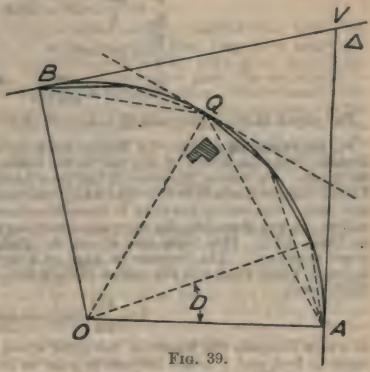


Fig. 39.

In locating curves on a line of railroad, many problems will come up for solution too numerous for description here. A knowledge of trigonometry and the use of formulæ in Table IX will solve any problem that may arise.

77. **Laying out curves without the use of instruments.**—See pars. 17–25.

78. **Reverse curves.**—A reverse curve should not be located in a line of railway unless it is impossible to avoid using it, and two curves, curving in opposite directions, should not be nearer to each other than at least the length of the longest train that it is expected to run over the line.

79. **Corrections for curves of over 10°.**—It will be seen that in the foregoing curve work there is a slight error, due to the difference in length between an arc and the 100-ft. chord used in chaining. This difference is inappreciable for curves up to 10°. For curves sharper than this, there is a measurable correction to be applied, especially when subchords are used. In locating a very **sharp curve,** points must be located less than 100 ft. apart to properly outline the curve. In fig. 40 it is desired to use n subchords, and to find the length, C′, of the subchord AB. $\frac{D}{n}$ is the angle AOB, subtended by subchord C′.

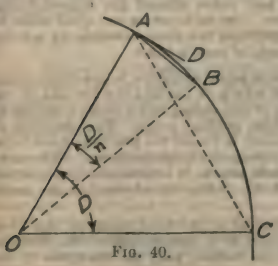


Fig. 40.

D = degree of curvature = AOC.

$$\text{Then, } C' = 2R \sin \frac{D}{2n};$$

$$\text{then, as } 2R = \frac{100}{\sin \frac{D}{2}},$$

$$C' = \frac{100 \sin \frac{D}{2n}}{\sin \frac{D}{2}},$$

$$\text{and } \sin \frac{D}{2n} = \frac{C'}{100} \sin \frac{D}{2}.$$

Example.—Required, to lay off a 36° curve with short chords so that a 100-ft. chord will subtend 36° at the center. What is the actual chord length to be used, when we wish to use three short chords?

$$\frac{D}{2_n} = \frac{36°}{6} = 6° = \text{BAD}.$$

$$\frac{D}{2} = 18° \, 00'.$$

$$\therefore \; C' = 100 \times \frac{\sin 6°}{\sin 18°} = \frac{10.45}{.309} = 33.81 \text{ ft.}$$

The chord 33.81′ is used and 6° is turned off for each such distance.

80. **Increase in gage.**—In laying track on tangents, the rails are laid with the distance from the inside of one rail to the inside of the other rail the exact gage of the track. On curves, however, it has been found better to slightly widen the gage. This is done on account of the rigid wheel base and the consequent wear of the wheels and rails. For curves less than 3° there is no increase in the gage of the track. For curves sharper than this, the increase, according to good American practice, is shown in Table XVI. This table also shows the **distance of the guard rail** from the inner main rail. The increase in gage on a curve is dependent upon the length of the rigid wheel base, and the radius of curvature. A general case can be found from the formula

$$I = \frac{3L^2}{2R} \text{ (approximately)},$$

in which L equals the length of the rigid wheel base in feet, R is the radius of the curve in feet, and I is the increase in gage in inches. This is an English rule and agrees with U. S. practice. I should never exceed about one-third of the tread. Note in Table XVI that the guard rail is a *constant* distance from the *outer* rail.

81. **Elevation of the rails.**—The elevation of the outer rail on a curve is dependent upon the radius of the curve, the speed of the train, and the gage of the track, and can be found from the following formula:

$$E = \frac{gV^2}{15R},$$

in which E is super-elevation in feet,
g is gage in feet,
R is radius in feet,
V is velocity in miles per hour.

82. In making this **correction for curvature**, the inner rail may be carried along at grade and the entire elevation may be given to the outside rail; or the center line may be carried at grade and the outer rail laid one-half the elevation above the center line, and the inner rail one-half the elevation below the center line. Whichever method is followed, the rails at the P. C. should have the full difference of elevation and the difference of elevation is run out on the tangent at the rate of about 1 in. in 60 ft. On a standard-gage military road the speed would doubtless be low, and a good rule for elevation for any curve would be ¾ in. for each degree of curvature, and the maximum elevation for any curve should not exceed 5 ins. Sharp curves and high speed do not go together. On such curves the speed must be cut down, and the allowable speed may be found from the above formula by solving for V. A slow sign should be posted at both ends of such a curve.

83. **The level party on location.**—The level party, as before, follows the transit party, and at each 100-ft. point sets a stake on which is marked the amount of cut or fill necessary at that point, and on each side of the center line a stake is driven to mark the foot of the slope, or the top of the slope at that point. The elevation of bench marks is checked, and if a great discrepancy is found the line may have to be run over from the last bench mark that was found approximately correct. Wherever a bridge of any sort is to be constructed, a **bench mark** is located and its elevation noted. This will facilitate the construction of the bridge in advance of the track work.

The elevations that are indicated by the stakes set by the level party on the location are referred to as the **subgrade.** This grade is a distance below the finished grade of the rail top equal to the thickness of the ballast, plus the thickness of the tie, plus the height of the rail.

84. **Ballast.**—For a temporary line, it will be impracticable to ballast the roadbed with anything except earth. There are thousands of miles of railroad in the United States with earth ballast, and, except possibly in cuts, it is not believed that any other sort of ballast will be necessary.

85. **Roadbed.**—The cross section of the roadbed must be decided upon before the level party starts on its last-mentioned work, in order that they may know the dimensions of the roadbed for which the stakes are to be set. Figs. 41–47 (pp. 29–31) show the dimensions of standard-gage roads. For any other gage, the slopes will be the same, but the shoulders outside of the ties will be slightly less. The difference will therefore be the difference in the gage of the tracks, plus twice the amount that the shoulder can be reduced in width. The dimensions of the roadbed of a 2 ft. 6 in. track would be, approximately, 11 ft. from shoulder to shoulder on a fill and 10 ft. from shoulder to shoulder in a cut. The dimensions for a track of 3-ft. gage will be about 12 ft. from shoulder to shoulder on an embankment and about 11 ft. in a cut. In excavations, plenty of depth should be allowed for **ditches** in order to insure a dry roadbed.

86. **Estimates.**—After the location survey has been made, notes are then at hand for making an estimate on the amount of material that must be moved, the other work that must be done, and the time necessary to build the proposed line. The estimates are made, if the work is to be done by contract, to obtain a basis on which the contract shall be let and upon which payment will be made; but in the normal case of a military line the work will be done by troops, or by hired labor, and the **object of the estimate** is to determine the quantity of work to be done at different points along the line in order to so subdivide the working parties as to get the best results and the quickest return in the shape of completed line.

87. In case an **official report** is desired by the G. C. before he decides whether or not to construct the line, the entire survey and the estimates must be finished before the report is made. This report will be accompanied by maps and profiles showing the routes considered and the final location decided upon, and the reasons therefor. It will also show the approximate cost of material and of civilian labor, the amount and cost of rolling stock and other equipment, and will show the capacity of the line when it is completed and the time that will be necessary to complete the work as desired. In case it has been definitely decided in advance to build the line, the cost and time are only considered in that they must be kept as low as practicable, and the survey need not be completed before construction work begins. A short section of location, 4 or 5 miles in length, is completed so that the working parties can be started, and thereafter it will be an easy matter for the survey parties to keep well in advance of the construction parties, since it is hardly practical for the construction party to average over a mile a day if conditions as to weight of track, number of bridges, and amount of excavation are not peculiarly advantageous. Even under favorable conditions as to construction, and with the use of light track, probably not over 3 miles a day can be finished. The survey parties can easily make more than this and will be able to keep ahead of the construction parties. (However, see par. 146.) It took 173 days to build 190 miles of the 3 ft. 6 in. railway from Wada Halfa to Abu Hamed, in 1897, on the latter part of which as much as 5,300 yards of line was built in a day. This road was built by Lieut. E. P. C. Girouard, R. E., British Army.

CONSTRUCTION.

88. Wherever the grades permit, the track will be laid directly on the surface of the ground and the necessary leveling up can be done after the track has been laid. It must be continually kept in mind that the first object desired is to get some sort of railway connection established, and that the betterments to the line in slight changes of grade, etc., can come afterward and not interfere with traffic.

89. Where a cut or fill is necessary, the **amount of excavation** or embankment is computed as follows: The areas of the cross section are computed, and where the changes are fairly uniform the volume of the section is equal to half the sum of the end areas multiplied by the distance between them. The **prismoidal formula**, which is the sum of the two end areas plus 4 times the middle area, divided by 6 and multiplied by the distance between the two end areas, gives a closer approximation where there is a great difference between the end areas; but for normal work the first formula is sufficiently close.

Having computed the amount of excavation or fill for any section, the labor and plant can be divided up so as to approximately finish the whole work on that section at one time and so permit the track laying to go on continuously.

90. **Organization of working parties.**—The actual organization of the working parties will depend upon the manner in which it is planned to move the earth. However, there are a few cardinal principles which will apply in every case.

91. The work must be **laid out** far enough in advance so that no working party, either teams or men, shall be idle through lack of orders.

92. The men and animals must be housed and fed as well as conditions will permit. For this purpose, a quartermaster and a commissary should be detailed, with a sufficient number of assistants to thoroughly handle these two important duties.

93. The **quartermaster**, or one of his assistants, will have charge of all tools and supplies. He will be responsible for getting them to the front when wanted, and for distribution before working hours and collection afterwards. He is responsible for all camps, camp equipage, and transportation.

94. The **commissary** is in charge of the messing in connection with his duties as commissary, and shall act as paymaster.

95. The **health of the men** should be looked after by a detail from the medical department, whose business it is to look after the sanitation of the camps, the proper policing of the water supply, and the general health of the men.

96. The **health of the animals** is also important, and a proper number of veterinarians should be employed to take care of them.

97. The camps will be so located that the least possible time will be lost in getting the entire force onto the work, and the camp will be moved from time to time to fill this requirement.

98. If necessary for the safety of the camp and the working parties, a **proper guard** will be detailed, whose commander will report to the engineer in charge of the party, or parties, that are to be protected.

99. The **guard commander** of the camp will be responsible to the engineer in charge for the security and safety of the camp and working parties. He will perform his duties in the manner prescribed for the outpost commander in the Field Service Regulations, and will keep the engineer in charge fully informed as to the precautions that he has taken, and will give him timely warning of an enemy's approach.

100. **Clearing and grubbing.**—The first party sent out clears the right of way of all trees, brush, etc., and is followed by a party to grub out stumps that lie in the actual roadbed wherever the fill is not over 2 ft. Stumps up to 12 ins. in diameter can be pulled by means of a **stump puller**, which requires the use of one team and two or three men. For stumps larger than 12 ins. in diameter it is probable that dynamite will be used. To get a stump out by this means a trench is dug around the stump from 2 to 4 ft. wide and of sufficient depth to uncover the main body of the stump. A hole is bored under the stump with a 2-in. auger, and one or two ½-lb. sticks of dynamite are pushed into the hole and exploded. This small charge springs a large opening under the stump, into which the necessary amount of dynamite or powder is deposited with a detonator. The hole is filled with earth, and a magneto-generator, of the Laflin-Rand type, is connected to the wires, and by forcing down the handle the charge is ignited.

101. **Earth work.**—The simplest but slowest method of handling earth is by means of plow or pick, and shovel, and laborer. The average amount of earth handled by this means per man will vary from about 10 yds. per day in hardpan to about 25 yds. per day in sandy loam. The material must be loosened by a plow to get the above results.

The workmen should be divided into gangs of from 20 to 30, and each gang placed in charge of an overseer. The work itself must be allotted, by stations, to the various gangs the night before, in order that they may go directly onto the work in the morning and lose no time waiting for orders. On **light cuts** the earth may be thrown from the cut to the side of the excavation, but where the earth must be thrown more than 6 or 8 ft., it can be moved more rapidly by means of scrapers.

ROAD BEDS.

EARTH BALLAST.

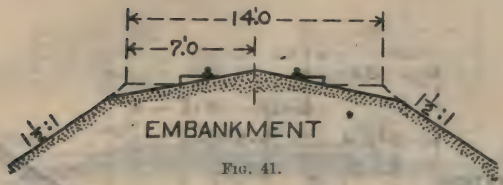


FIG. 41.

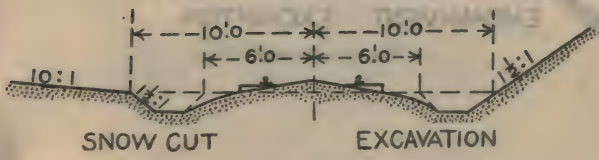


FIG. 42.—20-FT. BASE (UNDER 4 FT. IN DEPTH).

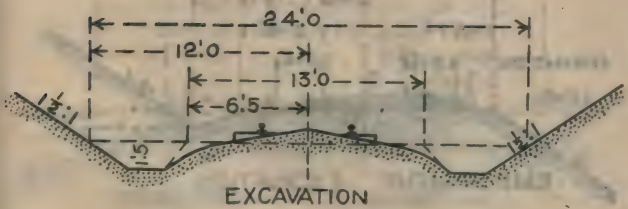
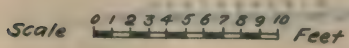


FIG. 43.—24-FT. BASE (4 FT. AND OVER IN DEPTH).



ROAD BEDS.

STONE OR GRAVEL BALLAST.

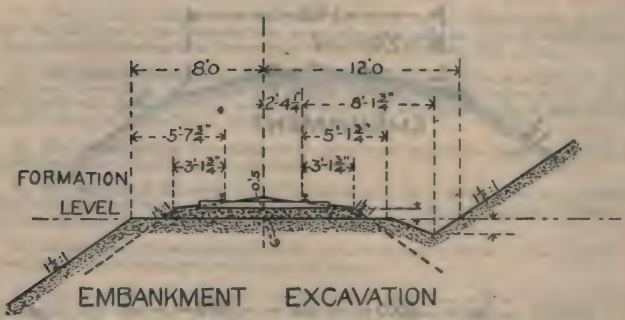


FIG. 44.—STRAIGHT LINE.

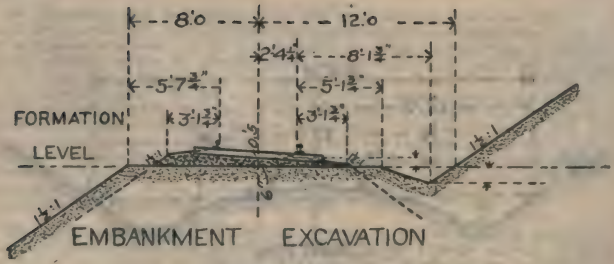
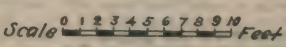


FIG. 45.—CURVED LINE.



ROAD BEDS.

GRAVEL BALLAST.

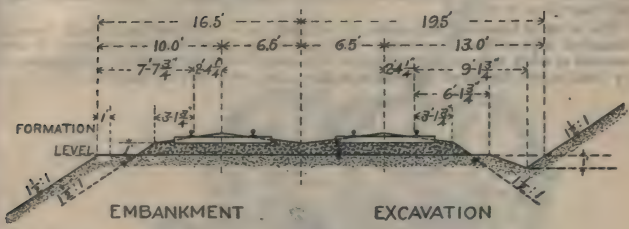


FIG. 46.—STRAIGHT LINE (DOUBLE TRACK).

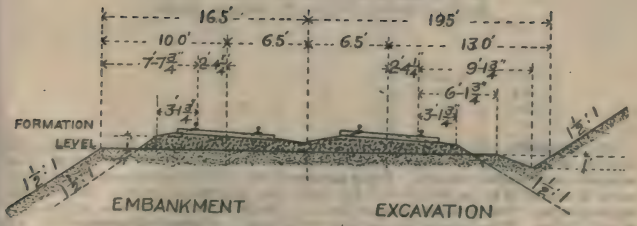


FIG. 47.—CURVED LINE (DOUBLE TRACK).

SCALE 0 1 2 3 4 5 6 7 8 9 10 FEET

No matter how the work is done, it should be impressed upon every workman that no stake is to be dug out of the ground, knocked down, or covered up without special orders.

On **embankment work**, under the most favorable conditions, the earth may be thrown direct from the borrow pit into the embankment, but the embankment must be rolled or tamped. The width of berm required may necessitate scrapers.

On **sidehill work**, the earth may be thrown direct from the excavation to the embankment on the side, and if the track is to be laid partly on the excavated and partly on the filled ground, an allowance must be made for the settling which will take place in the fill.

The work of loosening the earth can be much more profitably and easily done by means of a plow than by simply "picking" it by hand, and where there is any amount of work to be done this method will almost surely be followed. Moving earth by hand as just described is the slowest and most costly way of handling it.

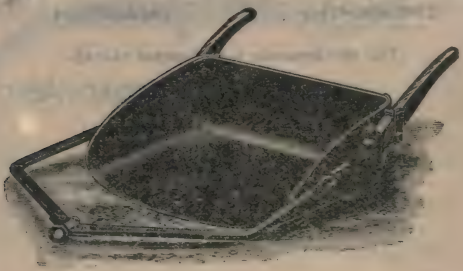


FIG. 48.—DOUBLE-BOTTOM DRAG SCRAPER (LAPPED CORNERS).

No. 1.—Capacity, 5½ cu. ft.; weight, 110 lbs.
No. 2.—Capacity, 4½ cu. ft.; weight, 100 lbs.

102. **Scrapers.**—A more economical way of handling earth, both in time and money, is by means of scrapers or machinery. Scrapers are of two kinds, drag scrapers and wheeled scrapers. **Drag scrapers** (fig. 48) are used where the embankment is under 10 ft. in height and the earth can be obtained within 100 ft. of the embankment. One of these scrapers handles about 5 cu. ft. at a time and weighs about 110 lbs. It is operated by one man and a team. A **wheeled scraper** (fig. 49) is for use where the embankment is higher than is suitable for a drag scraper and where the length of haul is from 100 to 600 ft. Beyond this, **wagons** or **cars** are more economical, if available. Wheeled scrapers have a capacity of from 9 to 16 cu. ft. and weigh from 400 to 750 lbs. For every four or five of these wheeled scrapers there must be an extra team, called a snatch team, to assist in loading the scrapers. If the ground is hard there must be one plow and team for every 25 or 30 scrapers. It is only in sand and loam that scrapers can be loaded without plowing up the ground.

Including the snatch teams and plow teams, the **average amount per team** that can be put up by an outfit using No. 2 or No. 2½ wheeled scrapers is from 25 yds., in very heavy soil, to about 50 yds., in a sandy loam; the length of haul in each case being 200 to 400 ft. and the length of day 10 hours.

FIG. 49.—WHEELED SCRAPER IN LOADING POSITION.

No.	Height of wheels.	Size of tire.	Axle.	Capacity.	Weight.
	Ins.	*Ins.*	*Ins.*	*Cu. ft.*	*Lbs.*
1	35	2¾ x ¼	1¾	9	400
2	40 or 42	3 x ⅜	1¾	13	600
2½	44	3 x ⅜	1¾	14	650
3	46	3 x ⅜	1⅞	16	750

The average amount per team that can be put up in 10 hours by drag scrapers varies from about 20 cu. yds. to 40 cu. yds., the length of haul being not more than 50 to 100 ft.

103. **Elevating graders.**—Where the earth can be obtained alongside the embankment to be built, and in shallow cuts not over 3 ft. in depth, the earth can be handled directly into the embankment or spoil bank with great advantage by what

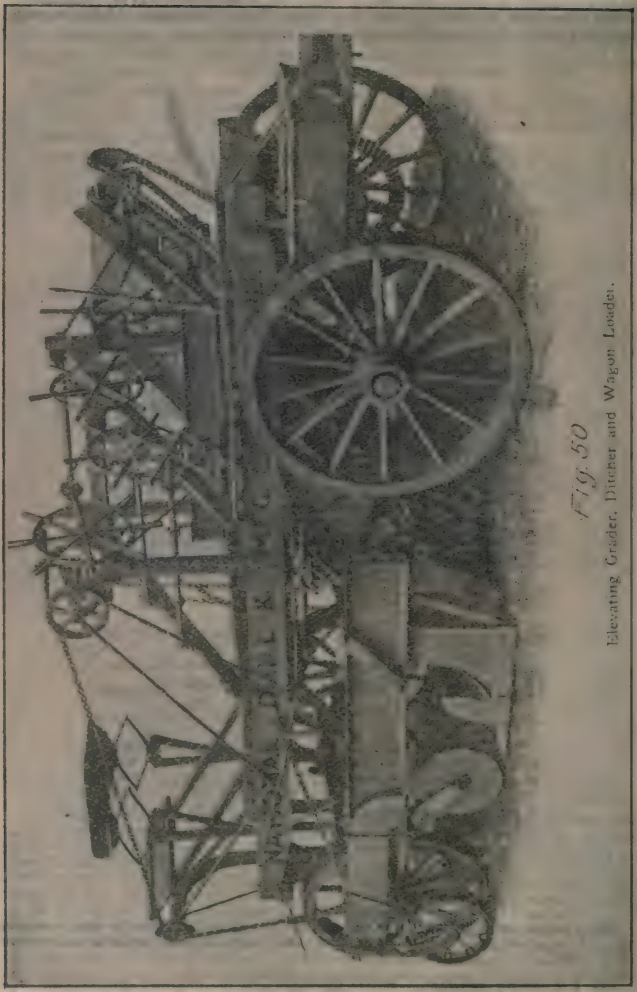


Fig. 50

Elevating Grader, Ditcher and Wagon Loader.

are known as elevating graders, a type of which is shown in fig. 50. These graders, on firm soil, can be well handled by a **traction engine**; but when water gets into the pit, or when the soil is soft, they can best be operated by three men and from six to eight teams. The plow under the machine cuts out the earth and throws it onto a moving belt which carries the earth up and discharges it from the end, either into a wagon moving along under the end of the conveyer or directly into the embankment or spoil bank. One of these machines will handle in good soil about 1,000 yds. of earth in a day of 10 hours.

Where a traction engine can be used, it will frequently be a saving to use one instead of the teams. The main objection to this grader is its weight, as it sinks into moist earth such a distance that the gearing becomes clogged and the machine will not work.

In cases where a **deep cut** is approached on each side by a high embankment it might be profitable to use these machines and dump wagons to dig the cut and make the embankment on each side.

The elevating grader can not be used in ground containing stumps until the land is thoroughly grubbed; but in many kinds of work, such as a long run of light fill or cut, in open country, where the material can be thrown out of the cut or into the embankment without a second handling, these machines can hardly be excelled.

104. The best sort of **wagon** to be used for this kind of work is a bottom dump wagon, illustrated in fig. 51, which holds about 1½ cu. yds.

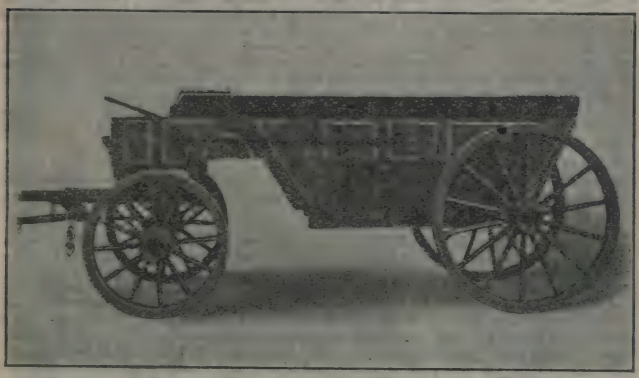


FIG. 51.—DUMP WAGON.

For a length of haul over 500 ft. the number of such wagons that can be kept busy by one elevating grader is about equal to the length of haul (one way) in feet divided by 70.

105. **Cuts and fills.**—For economy in the construction of a commercial line, an endeavor is made to keep the cuts and fills approximately equal when this can be done without an excessive amount of overhaul. This means that, wherever it is practicable, the earth taken out of the cuts is hauled into the embankment. On temporary field railway construction, where **economy of time**, and not that of labor, is the great problem, it is not feasible to make the cuts equal to the fills, and only in special cases would the earth be hauled away from a cut into an embankment for more than a few hundred feet from each end.

A greater amount of earth is handled in a given length of cut than in the same length of embankment, owing to the extra width necessary for ditching. Cuts are difficult to drain, and are the source of sliding banks. Aside from the extra cost of excavation, the main objection to cuts arises from the water in the soil, which is more difficult to take care of in a cut than in a fill.

If an endeavor is made to get all the material for the embankment from the adjacent cuts, the number of men, teams, etc., that can be put on the work at one time will be materially reduced.

From the foregoing it will be seen that embankments can be more easily and rapidly constructed and require less maintenance than cuts. On a military road the grades will be made so that the main part of the work will be in embankments or in shallow cuts.

106. **Berm.**—It is desirable to leave a berm along the foot of an embankment. The width of the berm varies with the height of the embankment and the class of the soil, but is of less importance on a temporary line than on a permanent one. With an embankment about 2 or 3 ft. in height, a berm of a foot or two will be sufficient in firm soil. This will be gradually increased, as the height of bank increases, to 5 or 6 ft. on a fill of 10 ft. The inner slope of the borrow pit should be graded down at a slope of about ½ to the bottom of the pit. Where the soil is not very firm or where the indications are that it is underlaid with soft material, the berm must be wide enough to so distribute the load that the foundation will not be squeezed out from under the embankment.

107. **Slopes.**—Dry earth, when thrown into an embankment, assumes a slope of 2 on 3. This is called the natural slope of earth. A stiff clay that is well drained will stand a much steeper slope than this, and for a short time may stand almost vertical. As soon as water gets into it, however, this same clay becomes one of the worst earths to deal with and will run almost like water. It should, therefore, ultimately be cut back on the flat slope of at least ⅓ if drainage is difficult and the bank is to stand some length of time. No fixed rule can be given for the side slopes in a cut. The slope at which earth will stand is entirely dependent upon the amount of water that will percolate into it. The original slope to be counted upon can be 2 on 3. A **ditch** should run along the top of the uphill slope to carry off surface water, and good ditches should be run along the sides of the track. The engineer must use his judgment and will be governed by the local conditions of the ground, the time he has to build the road, and the length of time that he expects to use the road. A slope of 2 on 3 will, in general, be used in embankment work.

In **excavating a cut,** the first work will be to get a roadway of the proper width cut through to the established subgrade. The work of cutting down the slopes, digging the side ditches, and digging the ditch along the uphill side of the cut can all be done later.

108. **Shrinkage.**—The earth thrown into an embankment will shrink a certain amount, even if it is put in by wheeled scrapers which travel over the bank many times. When the bank is built by wheeled scrapers the shrinkage is about 10%; when built with wagons, about 15%; when built with drag scrapers, about 20%; and when thrown up by hand or by an elevating grader it will be at least 25%, even though an effort be made to tamp or roll the material when being thrown in. The bank is therefore built an additional height to allow for this shrinkage or settlement. Thus, with wheeled scrapers, an embankment 5 ft. high will be built 5½ ft. high, and under the action of weather and loads will finally settle to about 5 ft. This percentage of shrinkage refers to vertical height and not to cross section. The figures above refer to loam. Other soils differ in the amount of shrinkage, but the proportional shrinkage given above holds for the different methods of handling the material.

109. **Blasting.**—If an outcropping of rock is encountered or a ledge of rock is uncovered in the excavation, it would rarely be profitable to remove it for a line of this character, but the line would be located around it. If the occasion arises and the rock must be removed, the detachment of engineer soldiers that has the necessary apparatus can properly be called upon to do the work.

110. **Marshes.**—Where a marsh is encountered on location, the line should be run around on firm land unless conditions demand that the marsh be crossed. This crossing may be made by an earth fill, built from each side, and it may be found that the work will be hastened if the intended line be first corduroyed with logs or fascines extending well out beyond the toe of the bank. Ditches may be dug to drain the marsh, and this will frequently better the condition materially. It may be found necessary to cross the marsh on a trestle, whereupon the problem becomes a bridge across a shallow stream with a poor foundation.

TOOLS AND APPLIANCES.

111. Many of the tools and appliances used in railroad work are so well known that no description is given.

Fig. 52 shows some of the tools that will be needed with every section gang, viz:

No. 1. Adz.
No. 2. Adjustable track level.
No. 3. Track jack.
No. 4. Pickax (clay pick).
No. 5. Rail tongs.
No. 6. Spike maul.
No. 7. Track wrench.
No. 8. Tamping bar.
No. 9. Claw bar.
No. 10. Lining bar.
No. 11. Scuffle hoe.
No. 12. Metal track gage.
No. 13. Punch.
No. 14. Track drill.
No. 15. Cold cutter.
No. 16. Monkey wrench.
No. 17. Rail clamp.

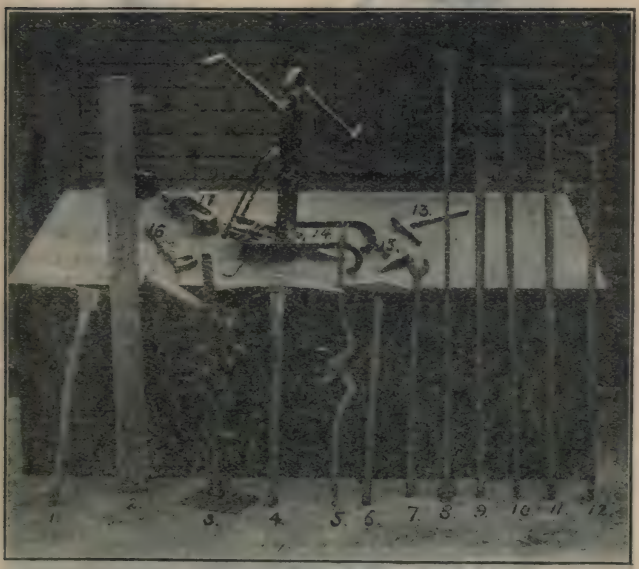


FIG. 52.—PRINCIPAL SECTION TOOLS.

112. **A tamping pick** has the same shape as a pickax, but has one end shaped like the head of the tamping bar. This kind of pick is useful in tamping rock ballast.

113. Fig. 53 is a **portable rail saw.**

114. Fig. 54 is a Gilman-Brown **emergency knuckle.** It can be used for a knuckle in practically every patent coupler except those that have no pivot-pin hole.

115. Fig. 55 is a **Barrett jack.** The strongest have a capacity of 30 tons. They are also made with a foot, or claw, for lifting track. Another widely and favorably known track jack is the **Jenne.**

FIG. 53.—PORTABLE RAIL SAW.

FIG. 54.—GILMAN-BROWN EMERGENCY KNUCKLE.

FIG. 55.—BARRETT JACK.

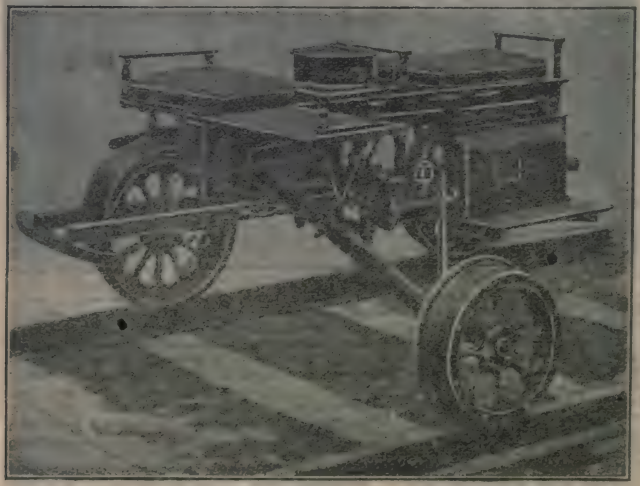


FIG. 56.—GASOLINE MOTOR CAR.

116. Fig. 56 is a gasoline **motor car**, and will be found useful in track inspection and patrolling. These cars are also made for hand and foot propulsion.

117. Fig. 57 is a **hand car** with a foot-brake attachment.

FIG. 58.

FIG. 57.—HAND CAR, FOOT-BRAKE ATTACHMENT.

118. Fig. 58 is a **Wells light.** It is useful for all kinds of night work where a portable light is needed.

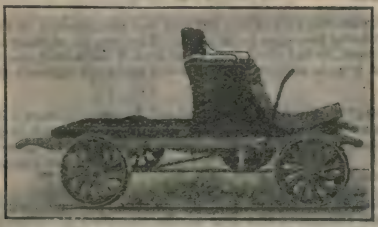


FIG. 59.—MOTOR CAR WITH TOOL DECK, TONNEAU REMOVED.

119. Fig. 59 is a gasoline **inspection car** that can be furnished with a tonneau for four, which is removable.

120. Fig. 60 is a **Sterlingworth holding-up bar**, which will be found very useful in laying track, since the blow to the spike is transmitted directly to the rail and not to the adjacent ties, as it is when the tie being spiked is held up from the adjacent ties by pinch bars.

FIG. 60.—HOLDING-UP BAR.

121. A **sand blast** is an appliance that will be found useful wherever iron work of rolling stock or bridges is to be cleaned for repainting. These sand blasts are a commercial article, and for cleaning metal work can not be equaled by any other method. The **nozzle** of a sand blast is the part that wears out quickest, and it has been found that a small piece of ¾-in. pipe pounded flat on one end and threaded at the other, for connection with the hose coupling, is as efficient as the best hardened-steel nozzles on the market.

122. With light rails the holes for track bolts can be punched, and a **portable rail punch** will be furnished for this purpose. Rails will be drilled when time and tools permit.

BRIDGES.

123. **Bridges.**—A discussion of the theory of the stresses and strains in bridges will not be considered here. The intention is to describe certain simple types of bridges and to suggest a system based on certain openings and loadings, in accordance with which the chief engineer may prepare, in advance, certain bridges or the material necessary for such bridges. If the work will be mainly reconstruction of an existing line, every effort should be made to obtain a **list of the existing bridges** and a description of each. These lists are kept by all railways. Preparation must then be made to duplicate every bridge on the line. If no such list can be obtained, or if a new line is to be constructed, certain openings shall be decided upon as standard. Knowing the maximum load, either steel or wooden stringers for these openings will be provided by the chief engineer. The engineer in the field, on coming to an opening where a bridge is required, will plan the bridge so that the openings between abutments, or between bents of piles or trestles, shall be from the lengths previously agreed upon and for which the chief engineer is prepared to send material without delay. This classification can only apply to **single openings**, because with several spans it will be impossible to include anything general about the necessary piers.

124. In any stream the rate of the current and the amount of drift are important factors in determining the span to be used. The length of time a bridge will be in use is also important, as the river may be at such a stage that one length of span can be used, when if it were at a higher or lower stage, an entirely different one would be necessary.

125. The **strength** of **wooden and steel beams** is shown in the tables under "Bridges," Engineer Field Manual, and also in the various engineers' and manufacturers' handbooks. The loads to be provided for can be ascertained or decided upon beforehand. The locomotive loads are the maximum loads and can easily be found for any standard locomotives.

126. On arriving at a river, or at a bridge that has been destroyed, the first consideration is to get some sort of a line across the river to connect with the road on the other side. This can frequently be done by making a **deviation** which will carry the roadbed into the river bottom and up the other bank, necessitating only a very short, low, bridge. This work is done by the advance party, and the second party follows and constructs the permanent bridge at the grade of the permanent track. Sharp curves on this diversion line should be avoided, since steep grades are inevitable and the combination may cause frequent derailments.

127. **Piers and abutments.**—Before the beams or trusses for the necessary spans can be decided upon, it is necessary to decide upon the location of the piers and abutments. The local conditions as to the banks and the bottom of the stream will, in general, determine the location and kind of abutments and piers that are to be used. In general terms, they will be either of piles, cribs, or trestles. A description of the methods and conditions that govern the use of these three and their method of construction is given in the Engineer Field Manual, Part II, under pars. 64 and 65 for trestle bridges, 66 to 70 for pile bridges, and 71 to 75 for crib bridges.

FIG. 61.

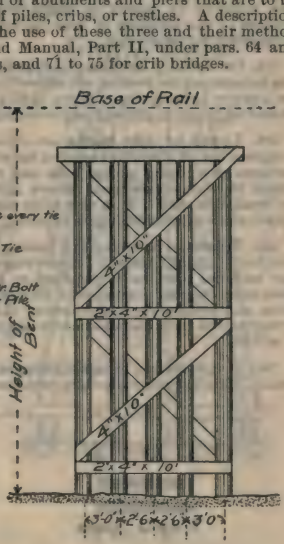


FIG. 62.

NOTE.—No bracing on bents up to 9 ft. high. Double bracing on bents over 18 ft. high and up to 28 ft.

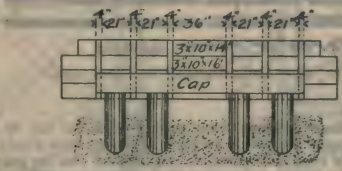


FIG. 63.—ABUTMENT WALL.

128. Unless the bottom is very muddy, a crib or trestle bridge can be built quicker than a pile bridge; and on this account, unless a pile bridge is necessary, one of the other two kinds will be used. The question whether **cribwork or trestles** will be built will depend upon the amount and kind of material at hand. Cribs can be built in a shorter time with unskilled labor than can trestles, but the amount of material in cribwork is greatly in excess of that in trestles.

129. Up to a height of 18 ft., crib piers can be built more rapidly than trestles if the material is at hand. Above this height, the advantage of the crib over the

trestle rapidly decreases; and above 25 ft. the trestle has the advantage. (Experience in South Africa.)

130. In trestlework it is frequently advisable to fasten the uprights to the caps and mudsills by means of **dogs** or **side plates,** instead of by **driftbolts,** on account of the difficulty of drawing driftbolts out of the timber in case the trestle is dismantled for future use.

131. On a **rocky bottom,** little difficulty is encountered in the foundations, as the bottom can be leveled off, either by cutting or by the use of concrete in bags. On a sandy bottom, two or three layers of ties make a very good foundation. Care should be taken to prevent any scouring under the foundation of the trestles.

132. **Types of pile bents** are shown in figs. 61, 62, 63. Table XVII gives a complete list of material required for any number of 16-ft. spans of pile bridge. It includes everything except rails and rail fasteners. It may be impracticable to obtain the wooden stringers shown in the table. In such a case steel I beams may be obtainable, and if so, a new table can be made incorporating such changes as the substitution of steel stringers requires.

133. **Beams.**—Knowing the loading, and having decided upon the location and number of spans necessary, the corresponding trusses or stringers can be taken from the material previously prepared, or the superstructure can be ordered from the base storehouse by a very short telegram. Work can be immediately begun on the piers and abutments, and knowing the height of rail and dimensions of ties and stringers, the piers and abutments can frequently be ready for the floor system when it arrives.

134. If it is desired to **lap stringers,** as shown in fig. 64, the telegram should so state. This lapping materially increases the stiffness of the bridge.

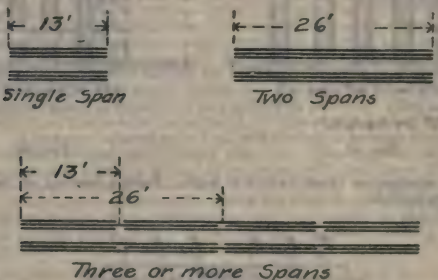


FIG. 64.—ARRANGEMENT OF STRINGERS.

135. In ordering a **floor system,** care should be taken not to ask impossible things. For instance, to ask for double lengths for a 15-ft. span would require timber 30 ft. in length, which is about the limit of length that can be supplied from the ordinary market; and if a longer span than 15 ft. were contemplated, it would not do to ask for double lengths unless it were known positively that such lengths could readily be obtained.

136. **Trestles.**—Figs. 65 and 66 show the form of construction for trestles of various heights and show the necessary bracings. From these figures and from fig. 67 bills of material for trestle bridges can easily be made up to suit any particular case.

137. The various methods of **erecting the trusses** or beams are fully described in the Engineer Field Manual, Part II, pars. 63 and 117. The ends of beams or trusses should be securely fastened to the caps by driftbolts or by some other method that

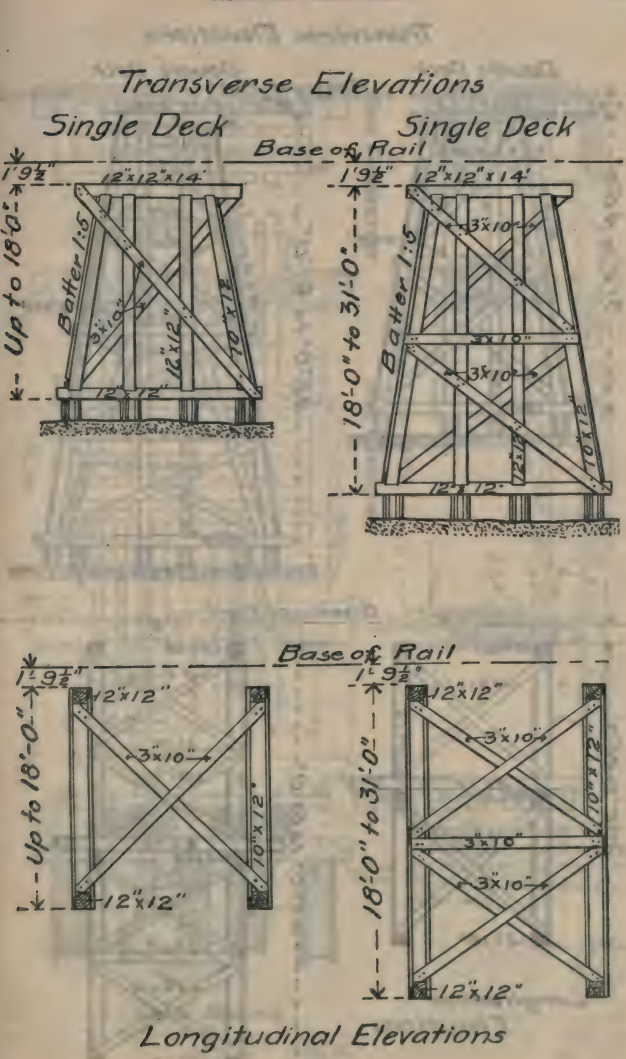

Transverse Elevations
Single Deck
Single Deck
Base of Rail
1' 9½"
12"x12"x14'
Up to 18'0"
Batter 1:5
3"x10"
12"x12"
10"x12"
12"x12"
1' 9½"
12"x12"x14'
18'-0" to 31'-0"
Batter 1:5
3"x10"
3"x10"
3"x10"
10"x12"
12"x12"
Base of Rail
1' 9½"
12"x12"
Up to 18'-0"
3"x10"
10"x12"
12"x12"
1' 9½"
12"x12"
18'-0" to 31'-0"
3"x10"
3"x10"
3"x10"
10"x12"
12"x12"
Longitudinal Elevations

FIG. 65.

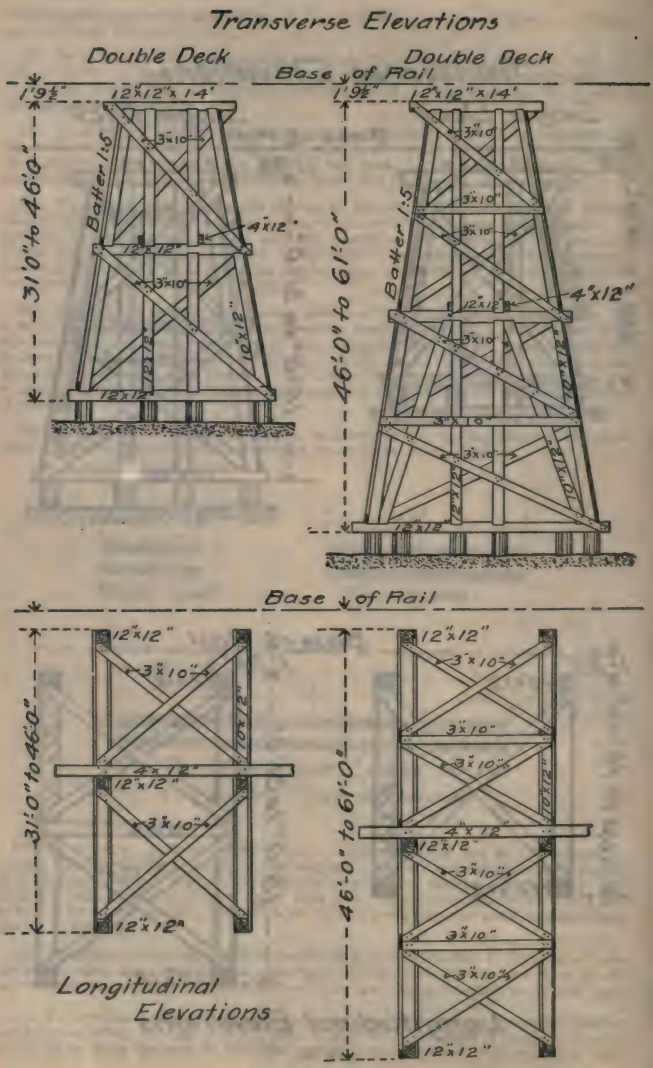

Transverse Elevations
Double Deck
Double Deck
Base of Rail
1'9½"
12"x12"x14'
1'9½"
12"x12"x14'
31'0" to 46'0"
Batter 1:5
3"x10"
4"x12"
12"x12"
3"x10"
10"x12"
12"x12"
46'0" to 61'0"
Batter 1:5
3"x10"
3"x10"
3"x10"
12"x12"
4"x12"
3"x10"
10"x12"
3"x10"
3"x10"
10"x12"
12"x12"
Base of Rail
12"x12"
3"x10"
10"x12"
4"x12"
12"x12"
3"x10"
12"x12"
31'0" to 46'0"
Longitudinal Elevations
12"x12"
3"x10"
3"x10"
3"x10"
10"x12"
4"x12"
12"x12"
3"x10"
3"x10"
3"x10"
12"x12"
46'0" to 61'0"

FIG. 66.

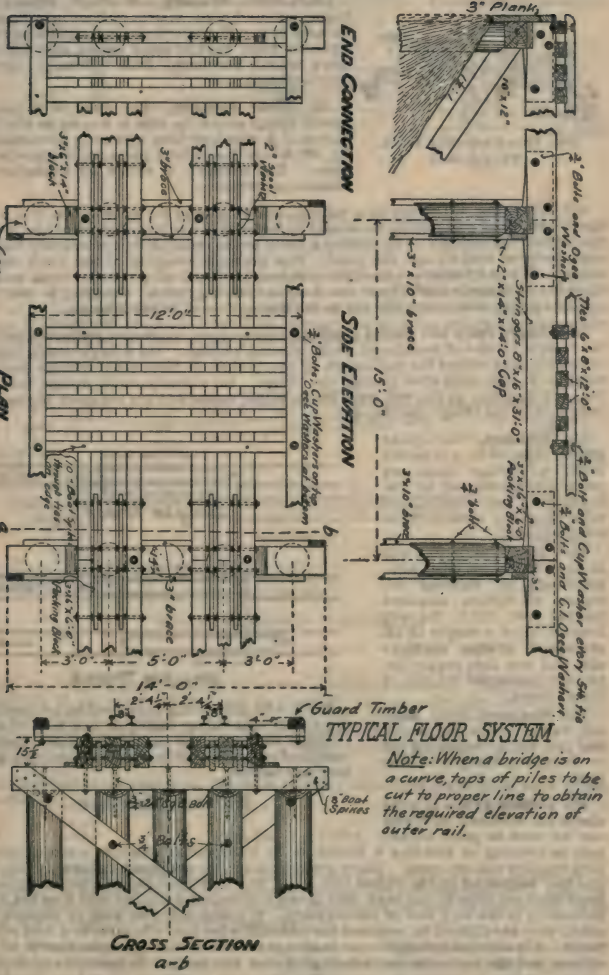

END CONNECTION
SIDE ELEVATION
PLAN
3" Plank
10"x12"
3"x6"x14" Block
3" brace
2" Spool Washer
Cap
12'-0"
15'-0"
3"x10" brace
12"x14"x14'-0" Cap
Stringers 8"x16"x31'-0"
Ties 6"x8"x12'-0"
Bolts and Ogee Washers
Bolt and Cup Washer every 5th tie
Bolts and C.I. Ogee Washers
Packing Block
3"x16"x6'-0" Packing Block
3" brace
3'-0"
5'-0"
3'-0"
14'-0"
2'-4½"
2'-4½"
Guard Timber
TYPICAL FLOOR SYSTEM
Note: When a bridge is on a curve, tops of piles to be cut to proper line to obtain the required elevation of outer rail.
8" Boat Spikes
CROSS SECTION
a-b

FIG. 67.

will keep them from sliding sidewise or lengthwise. Adjacent beams should be separated by blocks of wood, or by C. I. spools (see fig. 68).

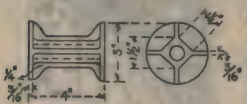


FIG. 68.—CAST-IRON SPOOL (WT. 1.5 lbs.).

138. **Cross bracing.**—Whether trusses or beams are used, some system of floor bracing must be used that will make the bridge rigid under side pressure from wind or other causes, and will prevent lateral movement from vibration due to moving loads.

139. **Floor system.**—The part of a pile or trestle bridge above the caps is known as the floor system. A standard floor system is illustrated in fig. 67, where the various parts are designated by name. The strength is varied by changing the number of stringers.

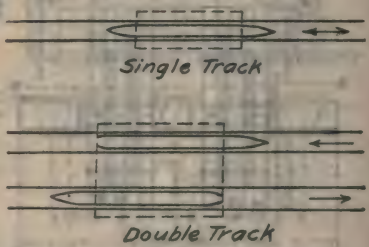
140. **Creeping.**—The ties of a railway bridge should be spaced from 4 to 6 ins. apart, and about every sixth tie should be fastened to the stringers, either by letting the tie into the stringer or by nailing a block to the stringer that completely fills the space between that tie and the next. This prevents creeping of the track on the bridge. When I beams are used for stringers, the track is prevented from moving sideways by fastening the ties to the flanges with lag bolts. Creeping is also prevented by clips that clamp the rail to the flange, or end, of the I beams.

141. **Guard rails** and **guard timbers** are necessary to prevent trains running off the bridges in case of derailment while crossing a bridge. On a single-track bridge, the guard rails extend the full length of the bridge on both sides and are brought together at both ends after leaving the bridge. On a double-track bridge, they are brought together at the end from which traffic comes and are left open beyond the other end of the bridge (see fig. 69).

142. **Trusses.**—For spans greater than 50 ft., a truss for a railway bridge could not practically be carried in the storehouse, but would have to be specially ordered from stock material.

The chief engineer will have on file in his office complete bills of material for trusses of various standard lengths (par. 123). He will keep on hand a supply of all **standard bridge materials,** and can thus supply the necessary material for any of these trusses.

The Engineer Field Manual, Part II, pars. 108 to 132 and par. 151, gives data of use in designing bridges of this type.



NOTE.—No guard rails to be used on bridges having a clear span under coping of less than 20 ft.

Guard timbers to be placed at proper distance outside of rails on all bridges except those with solid floor and ballast.

FIG. 69.—GUARD RAILS.

143. **Cableways.**—In some places an overhead cableway can be used to great advantage in erecting or building a bridge, or in transporting supplies across a stream that vehicles can not cross. There are two classes, the **ordinary cableway** (fig. 70) and the **balanced cable crane** (fig. 71). The first form can be quickly rigged if large trees are close to the bank, and is very convenient when the load does not have to come in to the very foot of the supports. If towers must be used to support the cable, they are difficult to erect and the material is too heavy to carry in a field equipment. A considerably longer span is always necessary than the actual width of the stream, and the load must be pulled uphill over one-half of its journey and is only

stable at the lowest point in the catenary. The balanced cable crane, on the other hand, can carry loads farther inshore than its points of support; the stress in the cable is constant whatever the position of the load, and only sufficient force to overcome friction is required to move the load along the cable. The key to the construc-

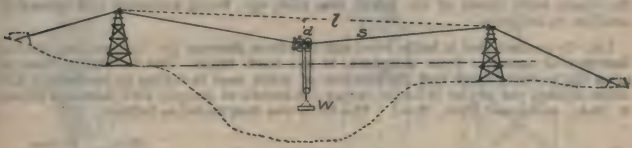


FIG. 70.—ORDINARY CABLEWAY.

tion of this cableway is that the length of the cable must be such that *both* counterweights can not rest on the ground at the same time. The automatic rising and falling of the counterweights as the position of the load on the cableway changes keeps the angles of the cable at the load symmetrical with the action line of gravity, and hence the load is stable at any point on the cable.

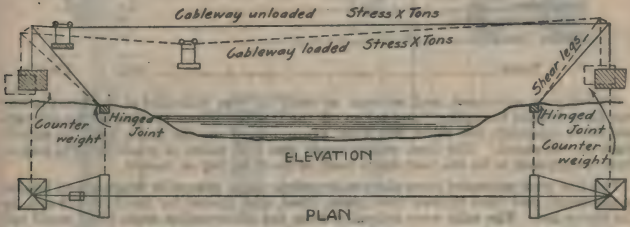


FIG. 71.—BALANCED CABLE CRANE.

One end only need oscillate, the other can be rigidly anchored. The cable can be supported at an intermediate point to diminish the sag, thereby decreasing the height of towers necessary. The counterweights are the only excessively heavy parts of this cableway. They will probably be bags of sand filled on the spot. The amount of material to be transported is comparatively small, and much of it will have other uses.

For efficient band operation, the cable of either class must have both ends at approximately the same elevation.

TRACK LAYING.

144. **Final center line.**—As soon as the roadbed is completed, the transit party runs over the line and sets center stakes 100 ft. apart on tangents and 50 ft. apart on curves, and re-marks the center of the track by tacks in the head of the stakes. The road is then ready for the track-laying gang.

145. **Track laying.**—The track-laying party now follows, and the plans for all preceding work should be such that the track laying can go on continuously. The **rapidity of track laying** is governed by the rate of supply of material at the

working point. This can be accelerated on sidetracks and on double-track work by unloading ties, rails, and other material directly from the cars alongside of the existing track, and work under these conditions is simple and rapid, for the material can be easily distributed.

On **new work**, however, the rails, ties, and all other materials must be either distributed along the line by the **use of wagons** or must be carried on a **train** and the track built ahead of the train; ties, rails, etc., being unloaded and placed in position by laborers.

146. On ground that is fairly level and free from streams the first method, that of distributing material from **wagons**, is the most rapid. The following example gives the working force and distribution of labor used in laying an average of 4.27 miles of track per day of 10 hours during the month of August, 1887, between Minot, N. Dak., and Great Falls, Mont. The force was distributed as follows:

	Men.	*Horses.*
Hauling ties	75	150
Loading ties	28	----
Distributing ties	10	----
Spacing ties	4	----
Lining ties	2	----
Marking and placing joint ties	4	----
Unloading flats and loading iron cars	24	----
Unloading iron cars and placing rails	13	----
Hauling rails	3	6
Spikers	38	----
Nippers	19	----
Strappers	12	----
Distributing spikes	2	----
Lining track	8	----
Total	242	156

Six rail cars were used, and as soon as each car was unloaded at the front it was run back behind the spikers and taken off the track. When the last of the six cars had been unloaded, the other five were again placed on the track and the supply train moved ahead. The best record made was 8.01 miles of track in 11½ hours. This is supposed to be the best day's work of track laying on record.

The ties were unloaded from the construction train, placed in wagons and hauled to the front, and then thrown into place, lined, and spaced by the first 123 men in the above list. The rails were unloaded from the construction train onto small rail cars, hauled to the front, and unloaded from these cars and placed on the ties by the next 40 men of the table. Rails were spiked to the ties, the bolts put in, and the track lined by the remainder of the crew.

147. The **organization and plant** required for rapid track laying by means of the second system will bear description, and apply not only to new work but also to the repair of breaks where a roadbed has been torn up by the enemy.

The party consists of 1 foreman, 3 subforemen, and from 80 to 100 laborers. The materials are carried on cars that are *pushed* to the railhead by a locomotive, Fig. 72 illustrates the arrangement of such a train, loaded with about 1 mile of railway material. The amount of material in such a train depends directly upon the weight of the rail and the size of the ties. On a standard-gage road a 40-ft. flat will carry about 1,100 ties or 125 to 150 rails (70-lb.). These loads are in excess of the rated carrying capacity of the cars, but the train moves very slowly and the loads can be safely carried.

148. A train should be made up to carry either a half day's or a whole day's supply of material, in order that no time shall be lost in going to the rear for new material during working hours. The first two cars are loaded with rails and the necessary angle bars, or fish plates, and bolts. The next two cars are loaded with ties. There will be one or two cars for the transportation of the working gang and for storing tools, spikes, and other supplies.

149. The ties and rails are supplied to the front by means of chutes that extend along the sides of the train. The dimensions and details of these chutes are shown in figs. 73, 74. They are supported by iron brackets, shown in

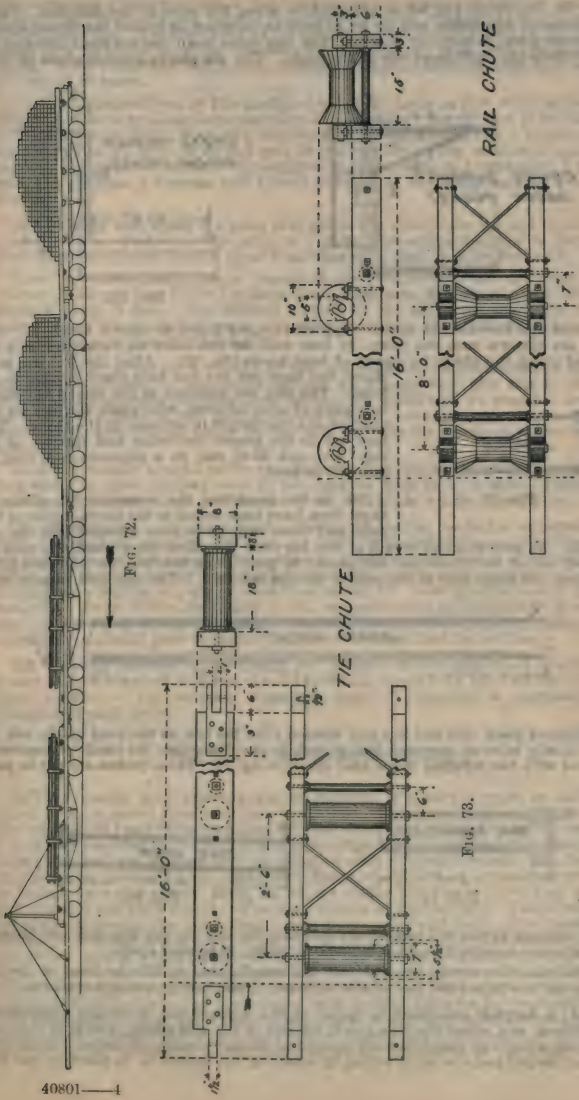


Fig. 72.

Fig. 73.

Fig. 74.

figs. 75, 76, which are set in the pockets along the sides of the flat cars. These brackets are adjustable, and are set at such an elevation as to give the chutes a slope of about 6 ins. in each car length. The ties come down the left-hand side and the rails down the right-hand side of the train. The **tie chute** extends about 30 ft. in

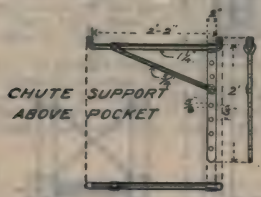


FIG. 75.

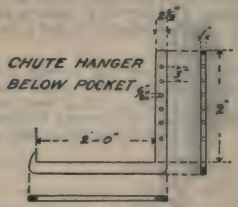


FIG. 76.

front of the forward car and is supported by guy ropes, as shown in fig. 72. The ties are thrown onto the chute by four men on the front tie cars, and they are pulled along the chute by means of boat hooks (fig. 78). After the ties are in th chute, one man per car can keep them moving to the front. The ties are received at the end of the chute by a gang of nine laborers, who place the ties on the roadbed one rail length in advance of the chute. Two men see to the proper centering and spacing of the ties. For each 30-ft. rail, on a standard-gage road, 18 ties will be used.

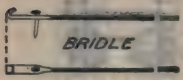


FIG. 77.

150. In the meantime, the necessary fish plates, or angle bars, have been bolted to the forward ends of two rails, and these rails have been dumped into the rail chute. As soon as a rail length of ties has been placed on the ground, the rails are pulled out of the chute and are placed in position on the ties, the rear ends going between the angle bars at the ends of the last rails laid. The rear rail man on each

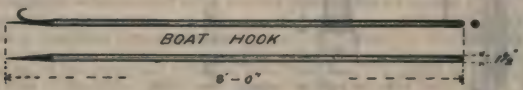


FIG. 78.

rail takes a track bolt and nut and wrench from the box on the head of the rail car and loosely bolts up one track bolt at each joint. Meantime the track is temporarily spaced with four **bridles** of the kind shown in fig. 77. These bridles are put in place

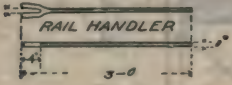


FIG. 79.

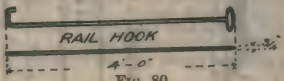


FIG. 80.

and fastened by the rail men after depositing the rail on the ties, and are brought up after the construction train passes over them, to be used again.

The train then moves forward one rail length, that is, till the head of the forward car is within a few feet of the railhead. Then the operation is repeated.

151. A **derrick** sometimes is rigged on the forward end of certain track-laying machines, and when the rails reach the end of the rail chute, which in this case extends a half rail length beyond the end of the car, a clamp is fastened to the middle of the rail and the rail is swung by means of the derrick to its place on the ties.

The advantage of this machine is that it decreases the number of laborers necessary to handle the rails, and this reduces the number of men working at the immediate head of the train. The tools used by the men on the rail car are shown in figs. 79, 80. These tools facilitate handling the rails and prevent the men from injuring their hands. With a machine like the one described, about 2 miles of track can be laid in a day of 10 hours.

152. The **composition of the party** ahead of the train on this work is about as follows, for 70-lb. rail, standard-gage ties: For handling ties, 18 men (4 on tie cars, 2 moving ties in chute, 2 spacing and centering, 9 carrying, and 1 subforeman); handling rails, 24 men (3 on rail car, 12 rail carriers, 4 clip carriers, 4 spike and angle carriers, and 1 foreman). In addition to these, there is 1 conductor, 1 brakeman, 1 engineman, 1 fireman, and 1 head foreman of the gang, making a total of 47 men.

153. **Behind the train** is a gang that spikes the rails to the ties and tightens all the track bolts. Following this gang is a gang that aligns the track to the stakes previously set. In the rear of these is another gang that surfaces the track.

These last three gangs are in charge of one subforeman, and are made up as follows: Bolting gang, 4 men; spiking gang, 4 spacers, 16 strikers, and 8 bar men; aligning gang, 8 men. The number of men in the surfacing gang will depend entirely upon the amount of work to be done in leveling the track, throwing in the earth ballast, and tamping the same.

154. In order to lay track rapidly by this last method, the joints must be opposite each other (square), or practically so; and on a temporary line this is the best method of laying track, as with earth ballast the joints will be pounded down by the traffic, and there is less danger where the low joints are opposite each other than there is with the low joints on one side opposite the middle of the rail on the other.

Rails are usually bought under specifications that 90% of the rails shall be 30 ft. long and the other 10% may vary by 2-ft. lengths from 24 ft. to 30 ft. These short rails can be used on curves and thus keep the rail joints nearly opposite each other.

155. **Expansion.**—In laying track, allowance must be made for expansion. A 30-ft. rail changes its length 0.252 in. for 100° change in temperature. Knowing the maximum and minimum temperatures of the place, thin plates, called expansion shims, can be made for use when laying steel at the various temperatures. For track laying before 10.00 a. m., use expansion shim for 10° lower than indicated by thermometer. From 10.00 a. m. to 4.00 p. m., use same shim as indicated by thermometer. After 4.00 p. m. use shim for 10° higher than indicated by thermometer. The thermometer should have the same exposure to the sun that the rail has.

156. **Laying narrow-gage track.**—If a light narrow-gage track is being laid it may be advantageous to fasten the ties and rails together at the rear and to carry these sections to the railhead, where the mode of procedure is practically that described in pars. 28–30.

TURNOUTS AND CROSSOVERS.

157. **Turnouts and crossovers.**—A turnout is a curved track by means of which cars are moved from one track to another. The special parts of a turnout are the frog (fig. 21) and the switch (fig. 19), and the guard rails. The term "switch" is frequently applied to the part of a turnout from the point of switch to include the frog. The **switch proper** may be either a stub or a split switch. The latter is the form now generally used. Stub switches are only used on unimportant lines or in yards. In a stub switch, EAD, fig. 84, is a single rail, free to move from A to D, but spiked to ties from E to A. The same is true of the rail BH. The switch rails are fastened together by connecting rods between point and heel. The **headblock** and **switch stand** are at the free end, D, of the switch rails. The arrangement of the switch rails of a split switch is shown in fig. 85. A turnout is always a curve as far as the frog, and the *general* case is a turnout from a curve. In the following discussion the **general case** is assumed to be the turnout from a curve whose radius is greater than the radius of the turnout, both centers lying on the same side. On this assumption there are **three other cases** which may be considered special: First, when the radius of a turnout curve is greater than the radius of the main-line curve, but its center is on the same side of the main line as the center of the

main-line curve; second, when the center of the turnout curve is on the opposite side to that of the main-line curve; and third, when the main line is a tangent, i. e., its radius is infinite.

158. Fig. 81 illustrates the general case considered.

$R = Oa =$ radius of the main-line curve.
$r = Ca =$ radius of turnout.
$\theta =$ angle of main-line curve subtended by BF.
$F = CFO =$ angle of frog.

$$n = \text{No. of frog} = \frac{1}{2} \cot \frac{1}{2} F.$$

At the point G, the line AF, produced, cuts the other rail of the main line.

$$\text{Then, } \tan \frac{1}{2} \theta = \frac{g}{2R} \cot \frac{1}{2} F = \frac{gn}{R},$$

$$r + \frac{1}{2} g = \left(R - \frac{1}{2} g\right) \frac{\sin \theta}{\sin (F + \theta)},$$

$$\text{and } BF = 2\left(R - \frac{1}{2} g\right) \sin \frac{1}{2} \theta,$$

$$\text{and } af = 2r \sin \frac{1}{2} (F + \theta).$$

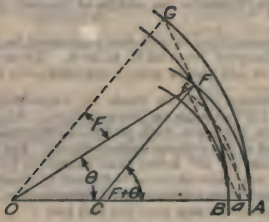


FIG. 81.

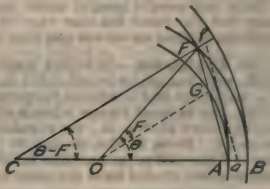


FIG. 82.

When R is greater than 500 ft. and n is a standard frog number, the degree of curvature of the turnout will be equal to the sum of the degree of curvature of the main track and the degree of curvature for the turnout from a tangent corresponding to n in Table XVIII or XIX.

$AD = \sqrt{\frac{10000\ DK}{t - t'}}$ (approx.), fig. 84, t and t' are the offsets from the tangent for 100 ft. on curves with R and r, respectively, as radii (see par. 23). Therefore, knowing radius of curvature of main line and of turnout and the throw of the switch, the switch length, AD, can readily be found.

In deducing the foregoing formulæ, R, r, θ, t', and F have been considered positive.

159. **First special case.**—$R < r$, t' positive, and F negative (fig. 82).

$$\text{Then, } BF = 2(R + \tfrac{1}{2} g) \sin \tfrac{1}{2} \theta \text{ (sign not considered).}$$

$$af = 2r \sin \tfrac{1}{2} (\theta - F) \text{ (numerically).}$$

$$AD = \sqrt{\frac{10000\ DK}{t - t'}}.$$

$$r - \frac{1}{2} g = \left(R + \frac{1}{2} g\right) \frac{\sin \theta}{\sin (\theta - F)}.$$

160. **Second special case.**— θ and F opposite signs, t' negative (fig. 83).

$$\theta = \text{FOA};\ \text{F} = \text{FOG};\ \text{F} - \theta = \text{FCA}.$$

Then, $\text{BF} = 2(\text{R} + \frac{1}{2}g) \sin \frac{1}{2}\theta$ (sign not considered).

$$af = 2r \sin \tfrac{1}{2}(\text{F} - \theta) \text{ (sign not considered).}$$

$$\text{AD} = \sqrt{\frac{10000\ \text{DK}}{t + t'}}.$$

$$r + \frac{1}{2}g = \left(\text{R} + \frac{1}{2}g\right) \frac{\sin \theta}{\sin (\text{F} - \theta)} \text{ (sign not considered).}$$

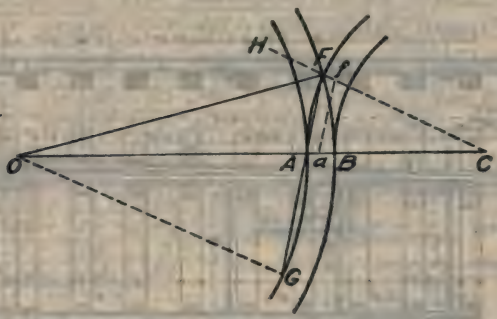


FIG. 83.

161. **Third special case.**—R = infinity, $\theta = 0$ $t = 0$ (fig. 84).

Then, $\text{BF} = g \cot \frac{1}{2}\text{F} = 2gn.$

$$af = 2r \sin \tfrac{1}{2}\text{F}.$$

$$\text{AD} = \sqrt{\frac{10000\ \text{DK}}{t}}.$$

$$\text{AD} = 100\sqrt{\frac{\text{DK}}{t}} = \text{BF}\sqrt{\frac{\text{DK}}{\text{AB}}} = \sqrt{2r\text{DK}}.$$

$$r + \frac{1}{2}g = \frac{g}{\text{vers F}}.$$

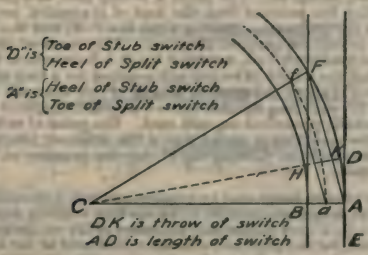


FIG. 84.

162. **To lay out a turnout** (split switch), fig. 85.—In laying out a turnout, the first thing to be determined is the point from which the turnout is to start, or else the location of the point of frog (P. F.). Having decided on one of these, and upon the number of the frog, the other may be computed by substituting in the proper equation for BF. The point B is called the theoretical point of switch, but is not the **actual point of switch** on account of the extreme thinness that would be necessary at the end of the switch rail, or the great length of switch rail that would be

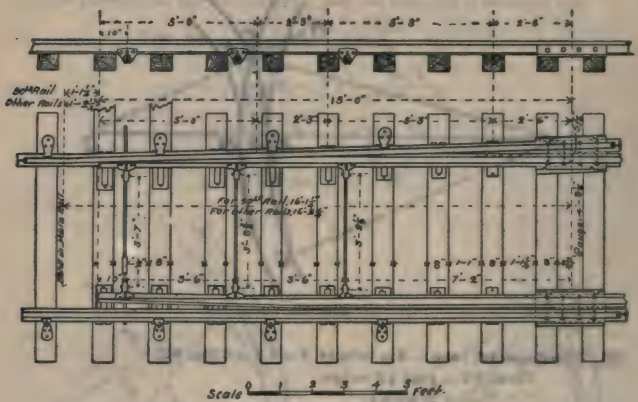


FIG. 85.—STANDARD SPLIT SWITCH.

required. The **toe of the switch** is the free end of the switch rail. The point D is called the **heel of the switch;** the distance DK is the clearance, or **throw.** These are all shown in fig. 84. The point A is only used as a point from which to measure in locating the point of frog, the heel of the switch, and the middle and quarter points for the ordinates. Having fixed the P. F. and the center line of the turnout, locate D to suit the required clearance. The length of the switch rails and the position of the headblock, etc., are fixed by D. Reference to Tables XVIII and XIX will show that the length of switch rail required for a frog above No. 7 is over 20 ft. Twenty feet is about the greatest length of rail that can safely be left free from the ties, and for each frog number above 6 a certain length of switch rail, called the "point," is usually prescribed on each road. The point of sufficient clearance is fixed, and then the headblock is placed where the arbitrary length of the "point" requires. See columns 5 and 6, table, fig. 87, for the practice on the Chicago and Northwestern Railway.

163. **Frogs** are usually designated by number, and this number, n, equals $\frac{1}{2}$ cot $\frac{1}{2}$ F. Sometimes **special frogs** are referred to by the frog angle in degrees and minutes. Tables XVIII and XIX give all the data necessary to lay out various standard turnouts from a tangent, for the gage, and clearance, indicated at the head of each table. For other gage, or clearance, the engineer can readily construct a similar table to meet his case.

Designation	Angle	CURVE Degree	CURVE Radius	P.C. to P.F.	H.B. to P.F.
1 in 5	11°25'16"	24°31'36"	235.4	47.08	
1 in 6	9°31'39"	16°57'52"	338.97	56.5	
9° SPECIAL	(For Double Slip)				
9° (1 in 6.353)	9°00'	15°07'	380.05	59.85	56'.75 1-30' Rail, 15' Point, 11'.25 Wing
1 in 7	8°10'16"	12°27'	461.1	65.92	61'.14 1-28' 1-14.89 Rails, 15' Point, 3'.25 Wing
1 in 8	7°09'10"	9°30'	603.8	75.33	67'.75 2-24' Rails, 15' Point, 4'.75 Wing
1 in 10	5°43'30"	6°05'	942.3	94.16	81'.50 2-30' Rails, 15 Point, 6'.5 Wing
1 in 14	4°05'26"	3°06'	1848.5	131.8	117'.27 3-30' Rails, 20 Point, 7'.3¼" Wing

Rail	Height	Head	Base
60 lb	4½ IN.	2 5/16 IN	4 7/16 IN
65 "	4⅜ "	2 5/16 " 2 13/32	4 7/16 "
72 "	4¾ "	2⅜ IN	4¾ "
80 "	5 "	2½ "	5 "
90 "	5⅜ "	2⅝ "	5⅜ "

No. 10-72 lb. same as No. 10-80 lb. excepting 6" bet. theoretical and actual Points.

9°-60 lb (17 ft. Frog) same as 9° 72 lb.

Present Width of Flangeways adopted 1895

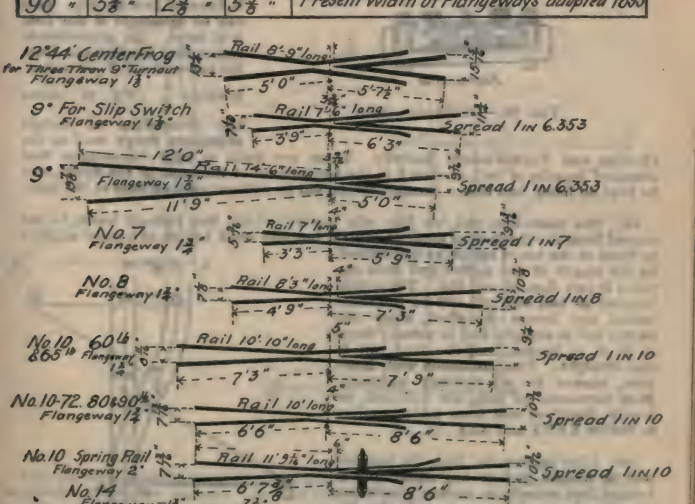


FIG. 87.

164. **On curves,** where R and r are both over 500 ft., very little error is made in taking BF and AD from the corresponding table for tangents; but where they are both under 500 ft., there will be considerable error and the values should be computed from the formulæ. These formulæ are also given on account of the great variety of existing gages in tracks in various parts of the world, and the impracticability of making up a table for every such gage, or throw.

165 Having located the point of frog and point of switch, the center of the turnout opposite each of these points is fixed by laying off $\frac{1}{2}g$ along the radius r. This locates the points f and a, fig. 84. Having located these two points, the **center line of the turnout** can be located by laying off from the middle of af, a distance equal to $\frac{1}{2}g$, perpendicular to af, and from the quarter points of af a distance equal to $\frac{1}{16}g$. The distance AD, taken from Table XVIII or XIX is laid off, locating the point D. At this point the distance from center to center of rails must be equal to d, the throw. Having located this point, and knowing the dimensions of the frog to be used, the rails will be cut, the frog put in, the remaining fixed rails spiked in place, and the switch proper is then put in. The **guard rails** are located well in advance of the point of frog so as to protect it from the wheels, the flanges being cut away, if necessary, to place them close enough together.

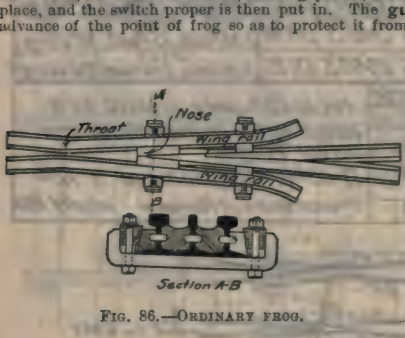


FIG. 86.—ORDINARY FROG.

166. For each special case, the turnout should be so located as to require the **least amount of rail cutting.** The actual point, or nose, of the frog is not the P. F. heretofore mentioned. The nose is blunted (see fig. 86). This can be measured if the frog is at hand. An approximate rule is that the distance from the nose to the P. F., in inches, is about $\frac{n}{2}$. Fig. 87 shows the dimensions of certain **standard frogs** used on the Chicago and Northwestern Railway. These are built to such dimensions that standard lengths of rail, as shown in the last column of the table in the figure, can be kept on hand, and thus a turnout can be put in without cutting rails at the time.

167. The main-line rail, on the side toward which the turnout leads, is not curved from the theoretical point of switch, but the bend begins at a point slightly in front of the toe of switch as determined by the length of the switch rail from the point D (see figs. 84 and 85). The actual turnout as laid out will not be the theoretical one herein described, since the switch rail is straight and is usually fixed at 15 ft. in length, and the frog rail is also straight. This discussion will, however, answer for all military purposes. Most turnouts, in fact, are laid out as herein described and from tables similar to Tables XVIII and XIX.

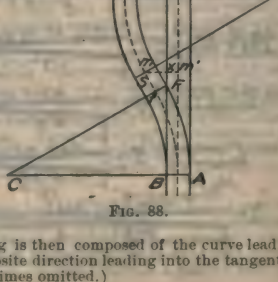


FIG. 88.

168. After passing the frog, the turnout will be located just as any other line is located, but sometimes certain conditions are placed upon a turnout, as in fig. 88. The condition here is that the turnout shall run parallel to the main line at a distance p from center to center. Such a siding is then composed of the curve lead, a short tangent, and another curve in the opposite direction leading into the tangent of the siding. (The short tangent fm is sometimes omitted.)

169. As a general rule, the second curve of this reverse curve is similar, but opposite in direction, to the first curve, although this is not necessary.

170. The **length of the tangent** S, fig. 88, is $\frac{p-g}{\sin F} - \frac{g}{\tan F}$, or approximately $\frac{p-2g}{\sin F}$; and Fx, on the main line, is $(p-g)$ cot F $- \frac{g}{\sin F}$, or approximately $(p-2g)$ cot F, or approximately $(p-2g)n$. The error of these approximations is 1% for a No. 7 frog, decreasing rapidly for larger-numbered frogs. Lay off this distance, S, from f, fig. 88, to m, making an angle, F, with the main line. This point, m, lies a distance $(p-g)$ from the center of the main line, and a distance g from the center of the proposed siding. This point, m, can be located without an instrument by laying off Fx from the P. F. along the center of main line to m', and at m', laying off $(p-g)$ perpendicular to the main line to m.

From m' lay off a distance m' N on the main line equal to BF, fig. 88, and from N lay off a distance p from the center of the main line and perpendicular to it. This locates the point, o, which is the P. T. of the curve leading to the siding.

The line mo corresponds to the line af, fig. 84, and the center line of the curve can be laid out in the same manner that the first curve lead was laid out.

171. The short tangent S may be omitted and the siding and main line may be connected by a **reverse curve** (fig. 89), r' being the radius of the second curve.

$$\text{Then, } p-g = \left(r' - \frac{1}{2}g\right) \text{ vers F, or } r' - \frac{1}{2}g = \frac{p-g}{\text{vers F}},$$

$$\text{and FN} = \left(r' - \frac{g}{2}\right) \sin \text{F}.$$

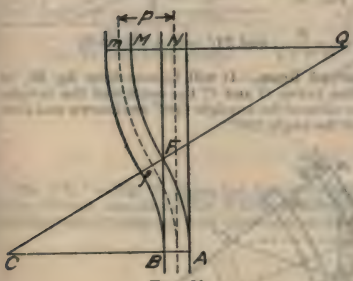


FIG. 89.

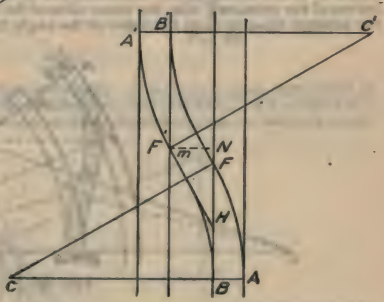


FIG. 90.

172. Another **special case** is where the turnout leads into another track. This is called a **crossover** (fig. 90). In case the lines to be connected are parallel, and p is the distance from center to center, the length of the tangent joining the two curve leads is found as in par. 170; that is,

$$\text{S} = \frac{p-2g}{\sin \text{F}} \text{ and FN} = (p-2g) \cot \text{F, or FN} = (p-2g)n \text{ (fig. 90).}$$

The point in the siding opposite to point N is the P. F. of the turnout of the second track.

173. As in the case of a siding (par. 171), the tangent S may be replaced by a **reverse curve** (fig. 91), in which case, if **both frogs** are **alike**,

$$\cos C = 1 - \frac{p}{2r},$$

$$PL = r \sin C = PL'.$$

The distance between points of frog measured along the main line is FN.

$$FN = 2\,(PL - BF).$$

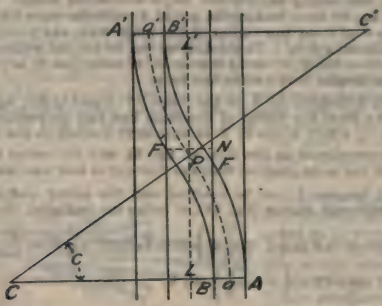


FIG. 91.

If the **frogs** are **different**, vers $C = \frac{p}{(r + r')}$, and $PL' = (r + r')$ **sin C.**

174. **To connect two parallel curved lines.**—It will be seen from fig. 92, in which O is the center of the main-line curve, C and C′ the centers of the reverse curves of the crossover, that the three sides of the triangle COC′ are known and that the solution depends upon the value of the angle COC′.

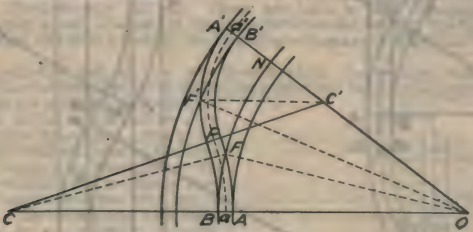


FIG. 92.

Let r = radius aC,
r' = radius $a'C'$,
p = distance between track centers,
R = radius aO,
a = COC′.

$$\text{Then, vers } a = \frac{p(r + r' - \frac{1}{2}p)}{(R + r)(R + p - r')}.$$

The arc $BN = 100\,\frac{a}{D}$ ft., in which D = degree of curvature of the main line.

$$\text{vers } C'CO = \frac{p(R - r' + \frac{1}{2}p)}{(R + r')(r + r')}.$$

The angle $CC'A' = a + C'CO$.

Knowing C′CO and CO′A′, the lengths of the arcs aP and Fa' can be found as BN was found above.

Knowing the frogs to be used, r and r' can be found from pars. 160 and 158 respectively, as can also BF and B′F′, remembering that the R of this paragraph must be increased by p when used in par. 158.

175. Another special case is found in **laying out a yard** where one distributing track leads from the main line and branches into several parallel sidetracks (see fig. 93). This is called a **yard lead,** or a **ladder track.** In this figure the distance p and the angle ϕ between the sidings and the distributing track determine the distance between points of frogs on the distributing track where the same numbered frogs are used throughout.

$$FF' = F'F'' = \frac{p}{\sin \phi}.$$

This distance FF′ must be greater than the half length of the frog used plus the length of curve lead (BF, fig. 84).

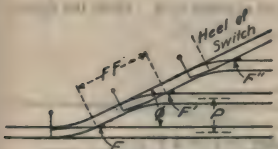


FIG. 93.—LADDER TRACK.

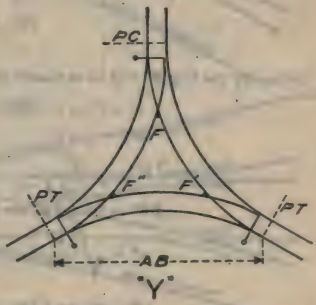


FIG. 94.

176. "Y."—Fig. 94 shows the layout for a Y. This form is most economical of space, though one side of the Y is frequently a tangent (fig. 94a). A Y consists of a combination of turnouts and curves, and from the figures can be laid out by an

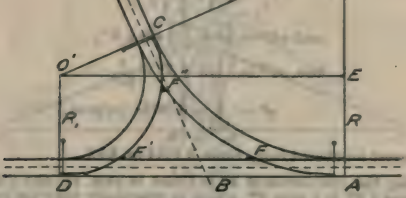


FIG. 94A.

application of the principles heretofore given for curves and turnouts. Figs. 94 and 94a are two of the simplest forms. There are several other combinations, but all of them present simple trigonometrical problems.

177. **A double turnout** is one where two tracks diverge from the main line, either on the same side or on opposite sides (see figs. 95, 96, 97). In fig. 95 the various distances for the first turnout are figured as in par. 161.

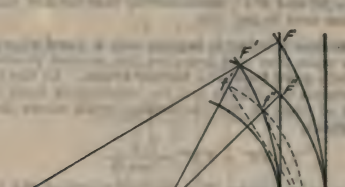


FIG. 95.

Ordinarily the frog F′ will be the same as F, and opposite to it. From the figure, then,

$$r' = C'a;\ r = Ca.$$

$$2r' = r - \tfrac{1}{2}g.$$

$$\text{vers } F'' = \frac{g}{r' + \frac{1}{2}g}.$$

$$BF'' = (r' + \tfrac{1}{2}g) \sin F'' = 2gn'' = g \cot \tfrac{1}{2} F''.$$

$$n'' = \sqrt{\frac{r'}{2g}}$$

$$af'' = 2r' \sin \tfrac{1}{2} F'' = \frac{2r'}{\sqrt{1 + 4n''^2}}$$

$$af' = 2r' \sin F.$$

The **throw of the second switch** is double that of the first.

178. When the turnouts are on **opposite sides of the tangent**, as before, F usually equals F′. Then, from fig. 97,

$$\text{vers } \frac{1}{2} F'' = \frac{g}{2\left(r + \frac{g}{2}\right)},$$

$$\text{and } aF'' = \left(r + \frac{g}{2}\right) \sin \tfrac{1}{2} F'';$$

$$\text{also, } aF'' = r \tan \tfrac{1}{2} F'' = \frac{r}{2n''}.$$

$$n'' = \frac{n}{\sqrt{2}} = 0.707n \text{ (approx.)}$$

For n'' use nearest numbered frog, Table XVIII or XIX.

179. Comparing the two values of F″ as found in pars. 177 and 178, it is seen, by assuming the vers $\frac{1}{2}$ F″ = $\frac{1}{2}$ vers F″, which is practically true for ordinary values of F″, "that a set of frogs (F = F′, and F″) which is adapted to a double turnout in opposite directions from a straight line (as in fig. 97) is also adaptable to a double turnout on one side (fig. 95), the curves being simple curves in both cases. This being true, the set is also adapted to a double turnout in opposite directions from any curved track, the radius of which is not less than r as given for F, since any such

case is intermediate between the two cases named."* Therefore, having adopted a frog number, n, for general use in double turnouts, another frog number, n'', should be adopted equal to $0.7071n$ for use as a secondary frog, F'', known as the **crotch frog.**

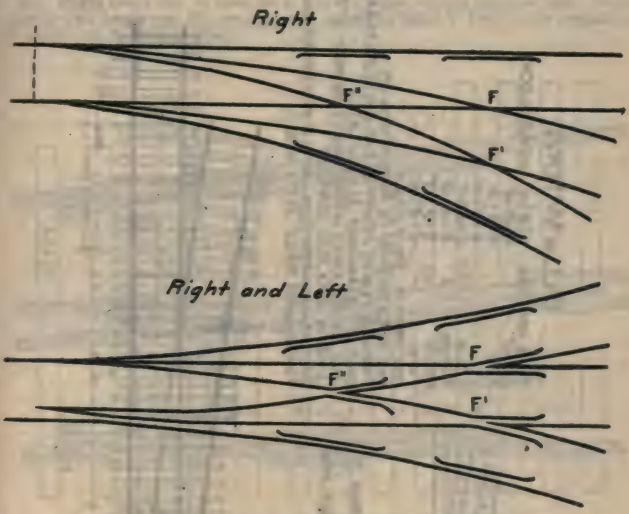


FIG. 96.—DOUBLE TURNOUTS, SHOWING FROGS AND GUARD RAILS.

180. **Frogs.**—The frog in general use for a crossover on standard-gage double track is No. 10. The frogs commonly used for leads to yards are Nos. 6, 7, and 8.

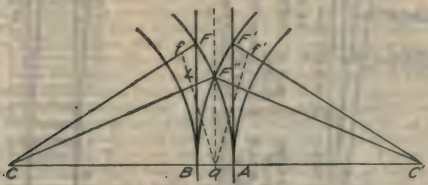


FIG. 97.

The V's in a frog and the openings at the ends of the wing rails should have blocks of wood driven into them. If left without such blocks, they are a great source of danger to switchmen running to throw a switch.

*Searle's Field Engineering, p. 155.

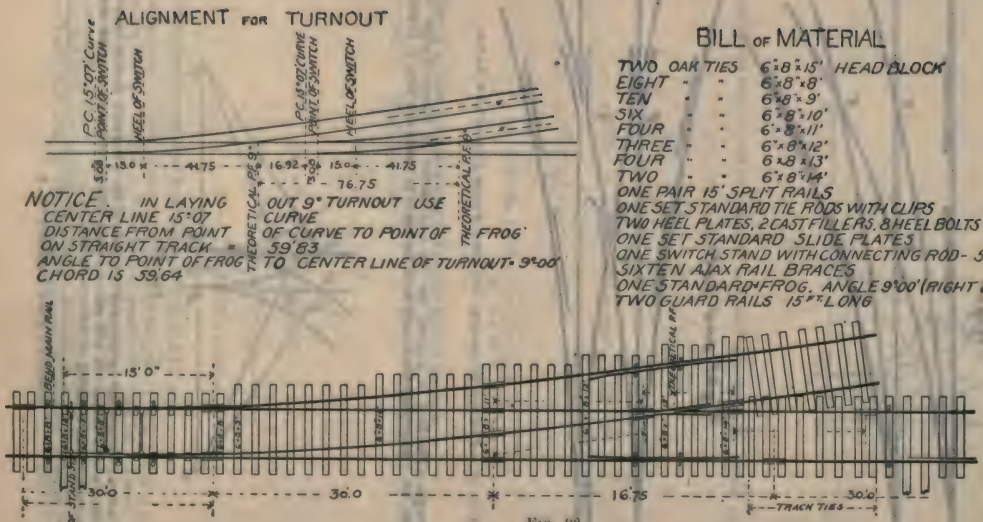

ALIGNMENT FOR TURNOUT
P.C. 15°07' Curve
POINT OF SWITCH
HEEL OF SWITCH
P.C. 15°02' CURVE
POINT OF SWITCH
HEEL OF SWITCH
THEORETICAL P.C.
THEORETICAL P.C.
13.0
41.75
16.92
15.0
41.75
76.75
NOTICE. IN LAYING OUT 9° TURNOUT USE
CENTER LINE 15°07' CURVE
DISTANCE FROM POINT OF CURVE TO POINT OF FROG
ON STRAIGHT TRACK = 59'83
ANGLE TO POINT OF FROG TO CENTER LINE OF TURNOUT = 9°00'
CHORD IS 59.64
BILL OF MATERIAL
TWO OAK TIES 6"x8"x15" HEAD BLOCK
EIGHT " " 6"x8"x8'
TEN " " 6"x8"x9'
SIX " " 6"x8"x10'
FOUR " " 6"x8"x11'
THREE " " 6"x8"x12'
FOUR " " 6"x8"x13'
TWO " " 6"x8"x14'
ONE PAIR 15' SPLIT RAILS
ONE SET STANDARD TIE RODS WITH CLIPS
TWO HEEL PLATES, 2 CAST FILLERS, 8 HEEL BOLTS & NUT LOCKS
ONE SET STANDARD SLIDE PLATES
ONE SWITCH STAND WITH CONNECTING ROD - 5" THROW
SIXTEN AJAX RAIL BRACES
ONE STANDARD FROG, ANGLE 9°00' (RIGHT OR LEFT HAND)
TWO GUARD RAILS 15' LONG
HEAD MAIN RAIL
15' 0"
THROW OF SWITCH STAND
30.0
36.0
16.75
30.0
TRACK TIES

FIG. 98.

181. **Ties.**—The arrangement of ties in a turnout can be seen in fig. 98. The main point is to have the ties at the joints so placed as to properly support the joints. The location of the guard rails is shown in fig. 96. The distance of these rails from the main rail is given in Table XVI, first finding the degree of curvature of turnout from Tables XVIII or XIX.

182. **Rigid frogs** can be used for a turnout either to the right or left. When **spring rail frogs** (fig. 99) are used, care should be taken to state in the requisition to which side the turnout leads.

FIG. 99.—STANDARD SPRING RAIL FROG (SPREAD 1 IN 10).

183. **Location of turnouts.**—It has been stated in various places that in turnouts from curves having a large radius, the dimensions given in Tables XVIII and XIX for turnouts from a tangent can be used with little error. However, in a turnout from a curve, the curvature of the turnout for a given frog is different from the curve of turnout from a tangent, and is equal to the curve of the main line plus the curve of the turnout from a tangent for a corresponding frog. The lengths of rail would not be exactly the same on the turnout from a curve as they would be on a turnout from a tangent. On account of this, and because of the desirability of having a number of turnouts ready for use at any time, it is best to locate all turnouts on tangents, where practicable. These ready-made turnouts should include all material for the turnout, as shown in bill of material, in fig. 98, so that by leaving out an exact number of 30-ft. rails the track laying can be continued; and when the turnout is put in place the opening left will be exactly filled. **Frogs** and **switches** can either be bought outright from equipment companies or can be made in the shops. The separate parts of a **split switch** are shown in fig. 85; those of a **frog** in fig. 86.

184. **Compound curved turnouts.**—The curves used in laying out turnouts and crossovers are ordinarily arcs of circles and are usually simple curves. It may happen that no frog is at hand, in laying out a double turnout, that will permit a simple curve to be run from the heel of the switch to beyond the farthest frog. In this case, use the frog that will require the sharpest curve as the crotch frog, allowing the flatter curve to lie between the two frogs. F″ must not be greater than 2 F.

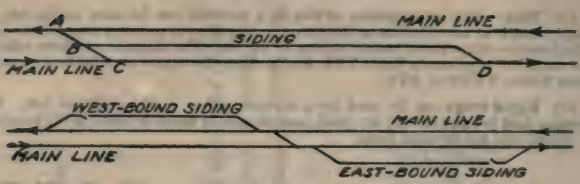
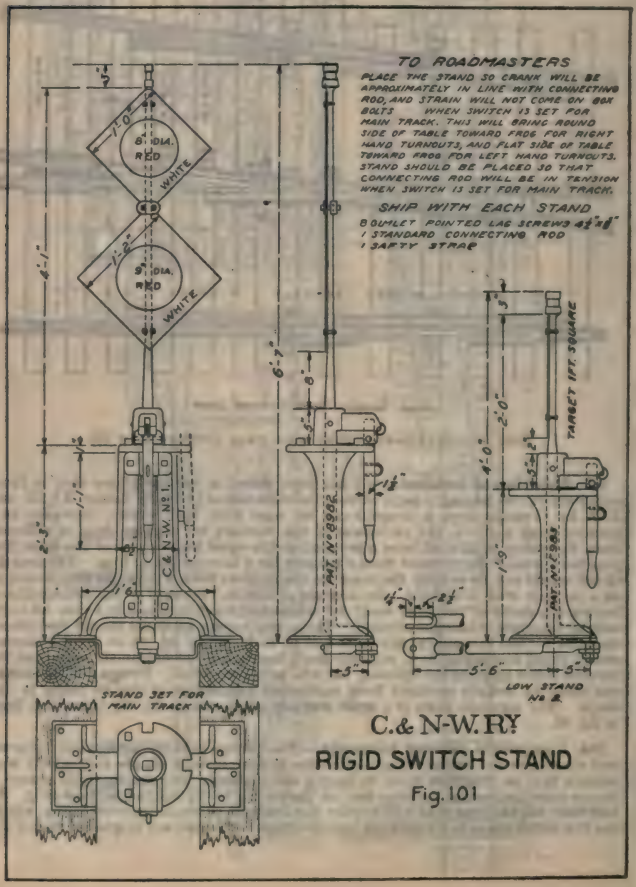
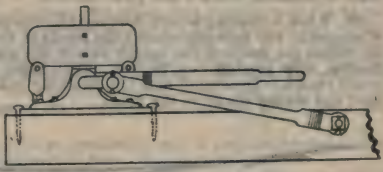

A
MAIN LINE
SIDING
B
MAIN LINE C
D
WEST-BOUND SIDING
MAIN LINE
MAIN LINE
EAST-BOUND SIDING

FIG. 100.


TO ROADMASTERS
PLACE THE STAND SO CRANK WILL BE APPROXIMATELY IN LINE WITH CONNECTING ROD, AND STRAIN WILL NOT COME ON BOX BOLTS WHEN SWITCH IS SET FOR MAIN TRACK. THIS WILL BRING ROUND SIDE OF TABLE TOWARD FROG FOR RIGHT HAND TURNOUTS, AND FLAT SIDE OF TABLE TOWARD FROG FOR LEFT HAND TURNOUTS. STAND SHOULD BE PLACED SO THAT CONNECTING ROD WILL BE IN TENSION WHEN SWITCH IS SET FOR MAIN TRACK.
SHIP WITH EACH STAND
8 GIMLET POINTED LAG SCREWS 4½"x⅜"
1 STANDARD CONNECTING ROD
1 SAFTY STRAP
8" DIA. RED
WHITE
9" DIA. RED
WHITE
C & N-W. No 1.
PAT. No 8982
PAT. No 1983
TARGET 1FT. SQUARE
STAND SET FOR MAIN TRACK
LOW STAND No 2.
C.& N-W. RY.
RIGID SWITCH STAND
Fig. 101

185. **Facing and trailing points.**—These terms apply particularly to the switches of crossovers on a double-track line. A trailing point is one which the trains move over from the point of frog to the point of switch; and a facing point is one which the trains move over from the point of switch to the point of frog. A consideration of fig. 100 will show the advantage of trailing points, in that if the switch is set wrong the train will run through it, forcing the switch points aside. This will break the switch, but the train will not be damaged. On some roads the policy is to have all main-line switches trailing points, and although this requires a little more time in switching cars or going into a siding, it is safer.



186. **Switch stands.**—A switch stand is a mechanism by means of which the switch points are moved. Types of these are shown in figs. 101, 102. The largest kind is more readily seen than the smallest one, and would be used in cases where the engineman must be able to note a missetting of the switch. The smallest kind is the kind used in the interlocking plant, where it is next to impossible for a switch to be set wrong and the engineman not be notified of it long before he reaches the switch. The middle type is one that is commonly used in yards. Economy of space and weight might dictate the use of the smallest switch in all cases on a supply road. For **stub switches** these stands should be on the engineman's side approaching in a facing direction. For **split switches** they should be on the side of the turnout. Fig. 103 shows a simple form of a **three-throw**, ground-lever **switch stand.**

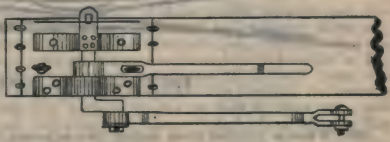


FIG. 102.

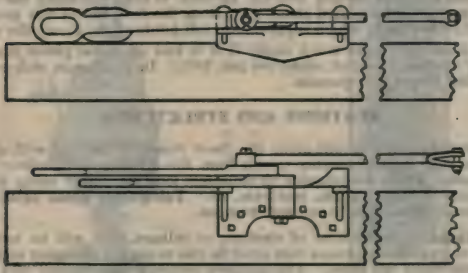


FIG. 103.—GROUND-THROW STAND FOR THREE-THROW STUB SWITCH.

187. **Crossings.**—When one track crosses another, a special piece of track construction, called a crossing, is put in. The best results are obtained when both tracks of the crossing and the rails for a foot or so on each side are in one piece, rigidly fastened together. This lessens the settlement, and what settlement there may be will be the same for the whole crossing. (For methods of measuring the angle of crossing, etc., see par. 38.)

188. When a crossing is very oblique, it is sometimes called a **diamond crossing.** When one or two turnouts connect the tracks at this point and each entire turnout lies within the limits of the longer axis of the diamond, it is called a **single, or double, slip switch** (see fig. 104). The latter is sometimes referred to as a puzzle switch. The switch rods for throwing these switch rails are quite complicated and are not shown in the figure.

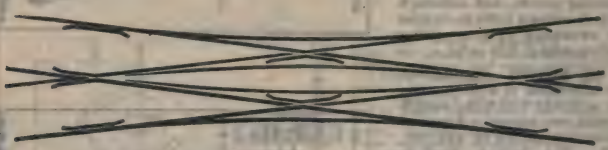


FIG. 104.—DOUBLE SLIP SWITCH.

189. When a turnout from one of two adjacent tracks must cross the other track, the line of the turnout is run until it crosses the center line of the second track. The common point of center is found and the angle of the crossing is determined as heretofore described.

190. **Stub switches.**—The occasion may arise when there will be no split switch on hand and it is desired to put in a turnout. The turnout can be put in as heretofore described, with the exception of putting in the split switch. It will be noticed in fig. 85 that it is only 16 ft. 1¼ ins. from the heel of the switch to the point of bending the main rail. By laying the main rails along the track from the left, fig. 85, as far as the heel of the split switch and leaving the last 16 ft. free from the ties, but connected by rods about 4 ft. apart, the free end of the track can be moved back and forth from the rails leading into the turnout to the rails along the main line. The switch stand will be located about 1 ft. from the free end of the movable rail; it rests on the headblock, which supports the rail joints at the toe of the switch.

The switch rail will move much easier if it is laid on metal plates that are well oiled. (For location of switch stand see par. 186.) In putting in stub switches *be careful to allow for proper expansion.*

STATIONS AND STRUCTURES.

191. **Mileposts.**—Every mile along the track should be marked with a conspicuous milepost, showing the distance to and from the division terminals or other important points. These are valuable in definitely locating points along the line, in making reports of engagements, accidents, etc. **Telegraph poles** should be similarly numbered, showing mile and pole number.

192. **Stations.**—The number of stations, or sidings, that will be necessary depends upon the number of trains that must be run to supply the army and the speed at which such trains can move. This distance between stations will vary according to the grades, but having the profile in hand and knowing the speed of the locomotives in miles per hour for certain grades and loads the distance apart of sidings can be determined, approximately, as follows: N is the total number of trains necessary to pass over the line in a day; T is the time in hours necessary for a train to pass from any station to the next one; $\frac{24}{N}$ is the maximum time in hours that can be allowed for a train to make the trip between stations. Not more than half this maximum value of T should be used in locating any two stations. In figuring this it must be remembered that the heavy loads are normally going to the front.

The amount of work that must be done at any station depends upon the location of the station, the number of buildings, and the length of auxiliary track that will be needed at that station to suit the local conditions. The questions of **water supply** and **storage room** at a station must be especially considered and are taken up later.

The **location of stations** may be determined by any number of military causes beyond the control of the locating engineer, but where such conditions do not fix the station, and the geography of the ground does not compel the location at any certain point, a study of the grades will be made as indicated in pars. 206, 207, and the stations located as above. The amount of siding, or passing tracks, that will be necessary at a station will have to be figured in each special case, and the minimum amount should be about two and one-half times the maximum train length contemplated on that division. The passing tracks are usually parallel to the main line (see par. 201, **Lap sidings**).

The **station sites** should be as level as practicable, and, if possible, located so that the yards can be seen by trains approaching from either direction.

An **open space** should be left near the tracks to facilitate the loading and unloading of troops, by allowing a systematic and orderly arrangement of the troops and their baggage in the immediate neighborhood of the station.

193. **Storage tracks.**—The number and length of these tracks depend upon the importance of the station, the number of troops that will be stationed there, the number of depot storehouses that may be located at that point, etc. A study of these items shows that each must be dealt with as it arises, and as it is impossible to tell how important a station may become at any future time, available track room will be left for additional loading platforms and storage tracks. In locating the storage tracks room should be left between the various tracks so that at least one, and preferably two, lines of wagons can drive in and receive freight from cars on the storage tracks.

194. **Water supply.**—The question of a good water supply is important for the troops that will be located at the station, as well as for railway purposes. This water supply will be obtained by means of hand pumps, steam pumps, or windmills. These pumps of various kinds are commercial articles, and their pumping capacity can be obtained from the various manufacturers.

FIG. 105.—PULSOMETER.

FIG. 106.—EMERSON STEAM PUMP.

A steam pump which apparently has great possibilities for field use is the **pulsometer** (fig. 105), and by means of it the locomotives can water themselves from streams, where the water can be used direct from the stream without having to allow it to settle.

Another pump, known as the **Emerson steam pump** (fig. 106) has the same good points as the pulsometer. Neither of these pumps requires any foundation. Both of them can obtain their steam direct from the locomotive (see par. 534).

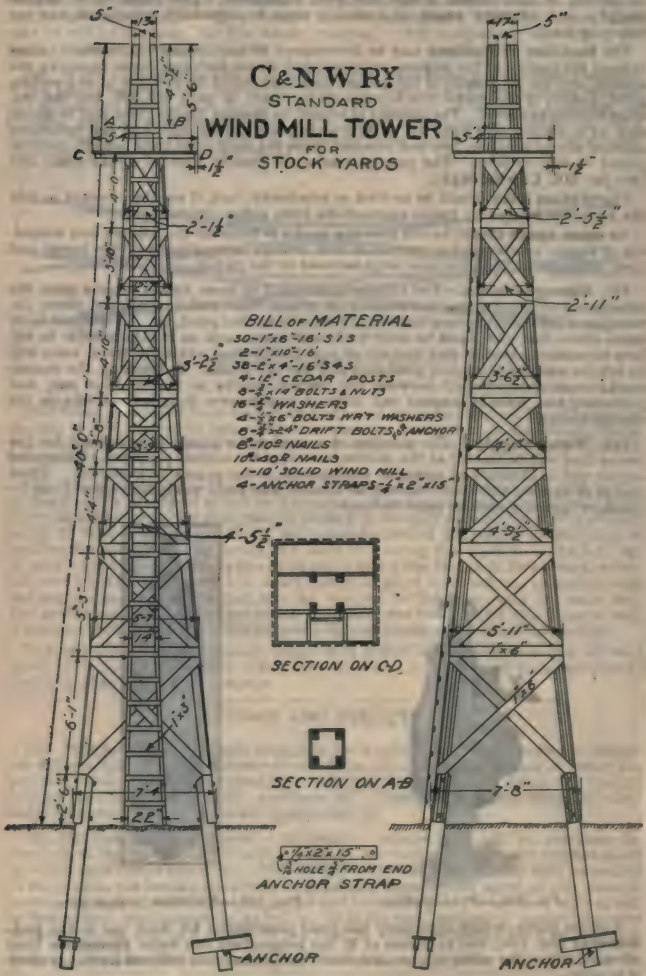
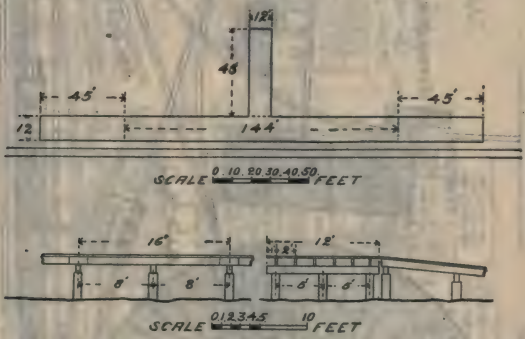

C&NWRY
STANDARD
WIND MILL TOWER
FOR
STOCK YARDS
BILL OF MATERIAL
30-1"x6"-16' S.I.S.
2-1"x10"-16'
38-6"x4"-16' S.4.S.
4-12" CEDAR POSTS
8-¾"x14" BOLTS & NUTS
16-¾" WASHERS
4-¾"x6" BOLTS W/T WASHERS
8-¾"x24" DRIFT BOLTS & ANCHOR
8"-10d NAILS
10"-30d NAILS
1-10' SOLID WIND MILL
4-ANCHOR STRAPS-¼"x2"x15"
SECTION ON CD
SECTION ON AB
¼"x2"x15"
¾" HOLE ¾" FROM END
ANCHOR STRAP
ANCHOR
ANCHOR

Fig. 107.

195. A bill of materials for a **windmill tower** is given in fig. 107. This is made up of small stock material and, on account of the lightness of the material, the tower can be easily built. Such a tower would be useful as a signal tower or observation station. For the storage of water at stations, metal or wooden **tanks** can be supplied and elevated to a position high enough to water locomotives. Wooden tanks of various sizes can be shipped knocked down. They occupy very little space in shipping and are quickly made ready for use. The size of the watering tanks for the railway will depend upon the capacity of the tanks of the locomotives. There should be one day's supply of water in storage at all times, if practicable.

For a movable water supply, **tank cars,** such as are used for the shipment of oil in this country, can be taken with the locomotive. This applies particularly to construction trains.

196. **Platforms.**—On every train length of siding there should be a platform at least 12 ft. wide and long enough to load three or four standard cars at one time. The tops of these platforms should be on a level with the bottoms of the car floors, and the platforms should have ramps leading to the ground at both ends and one in the middle, if the other tracks permit. These platforms are particularly useful in loading and unloading animals and vehicles and facilitate the handling of freight. Fig. 108 shows the platform and gives bills of materials for the whole platform and for each extra length of 16 ft.



BILL OF MATERIAL

FOR 16' PANEL		TOTAL	
Pieces	Dimen	Pieces	Dimen.
2	6"x10"x12'	32	6"x10"x12'
2	10"x10"x10'	20	10"x10"x10'
6	2"x10"x18'	108	2"x10"x18'
20	2"x10"x12'	345	2"x10"x12'

FIG. 108.—LOADING PLATFORM.

197. **Stockyards.**—At each station a stockyard should be constructed, and this should be connected with the side ramp of one of the loading platforms by a movable fence that can be thrown out of the way when the platform is desired for other purposes (fig. 129).

198. **Buildings.**—The buildings at the stations will be constructed after the line has been built. **Tents** can be used temporarily, and will answer every purpose.

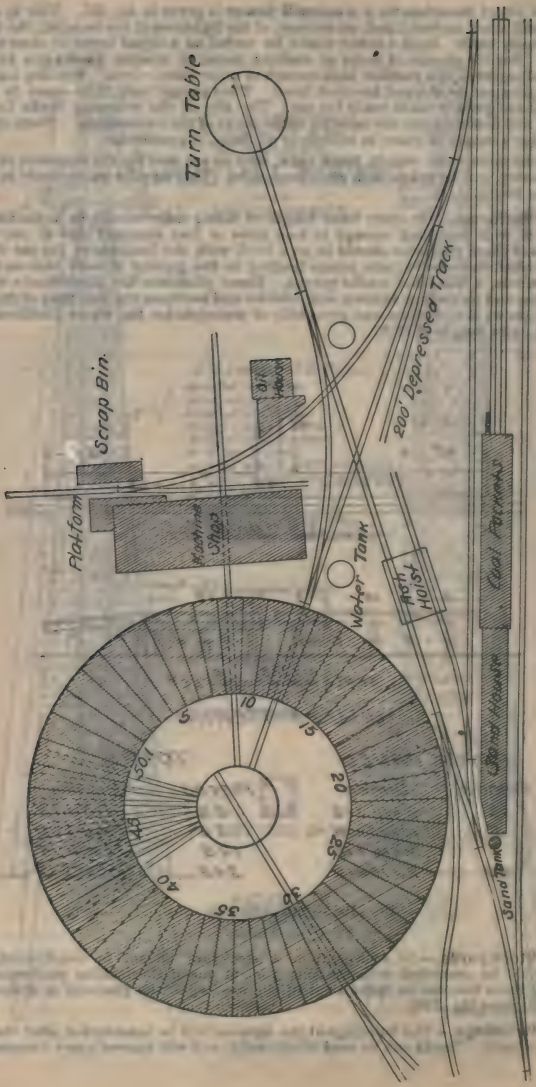
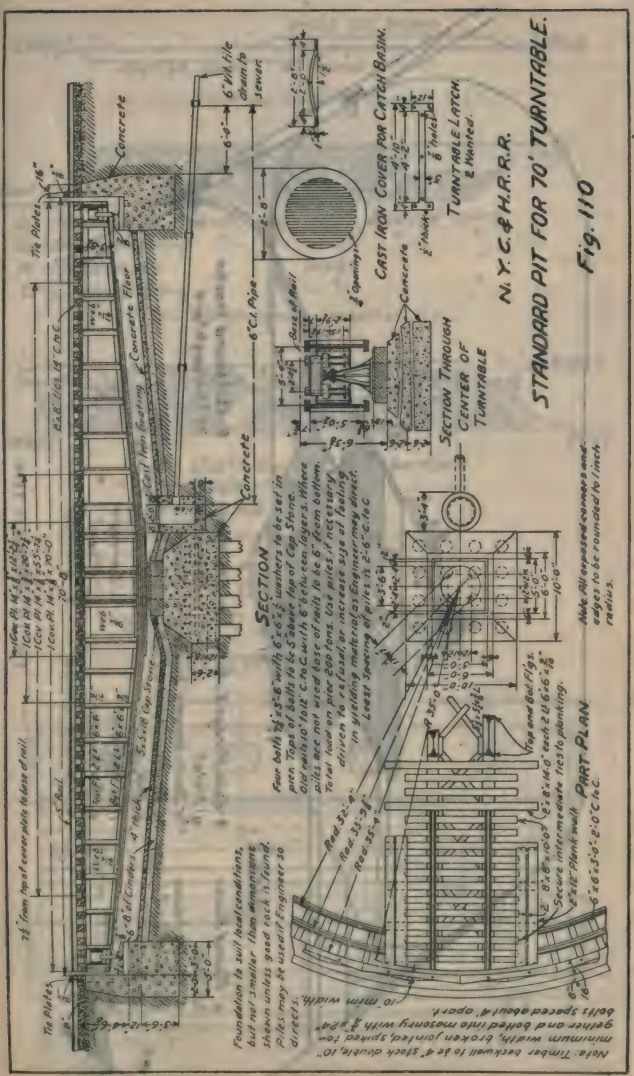


FIG. 109.—ROUNDHOUSE AND TRACKS.


N. Y. C. & H. R. R. R.
STANDARD PIT FOR 70' TURNTABLE.
Fig. 110
SECTION
SECTION THROUGH CENTER OF TURNTABLE
CAST IRON COVER FOR CATCH BASIN.
TURNTABLE LATCH. 2 Wanted.
PART PLAN
Note: Timber backwall to be 4" stock double, 10" minimum width, broken jointed, spiked together and bolted into masonry with ¾" x 24" bolts spaced about 4' apart.
Foundation to suit local conditions, but not smaller than dimensions shown unless good rock is found. Piles may be used if Engineer so directs.
Note: All exposed corners and edges to be rounded to 1 inch radius.
Tie Plates
Concrete
Concrete Floor
Cast Iron Grating
6" Vit. tile drain to sewer
6" C.I. Pipe
Base of Rail
Top and Bot. Flgs.
Secure intermediate ties to planking.
Secure Plank walk
10" mim width.

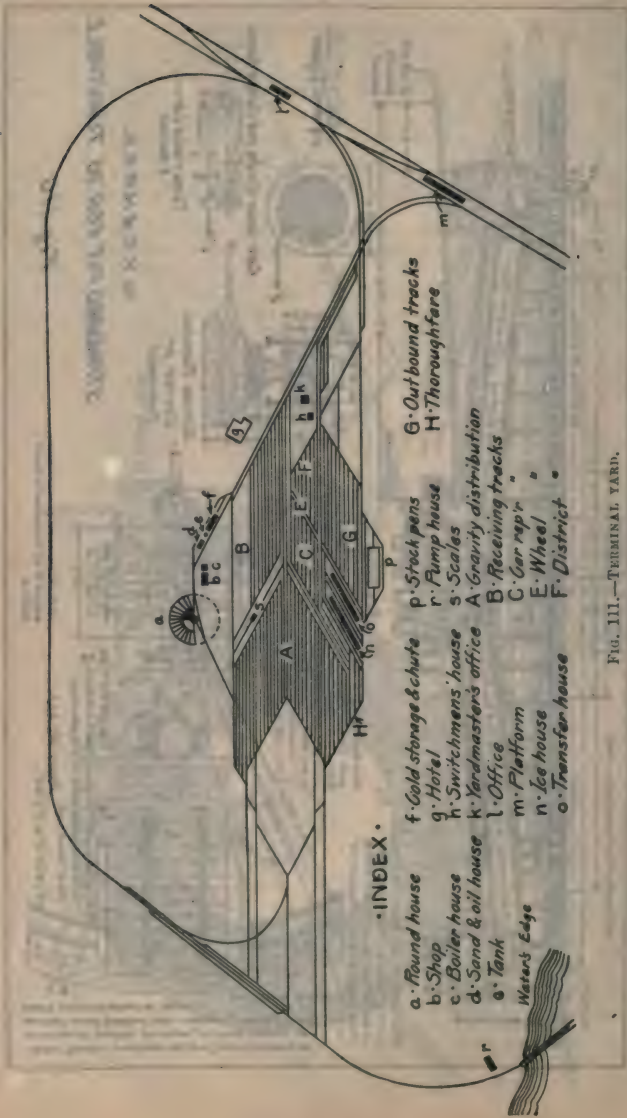


FIG. III.—TERMINAL YARD.

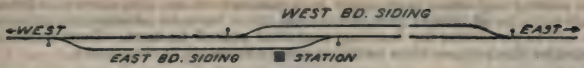


FIG. 112.—PLAIN LAP SIDING ON STRAIGHT TRACK.

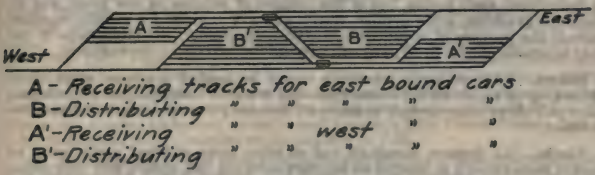


FIG. 113.—DIVISIONAL TERMINAL YARD.

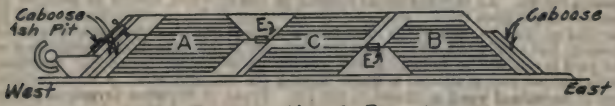


FIG. 114.—DIVISIONAL TERMINAL YARD.

C.&N-W. RY.

STANDARD 72, 80 & 90 LB RAIL JOINT

SHOWING

ALTERNATION OF BOLTS

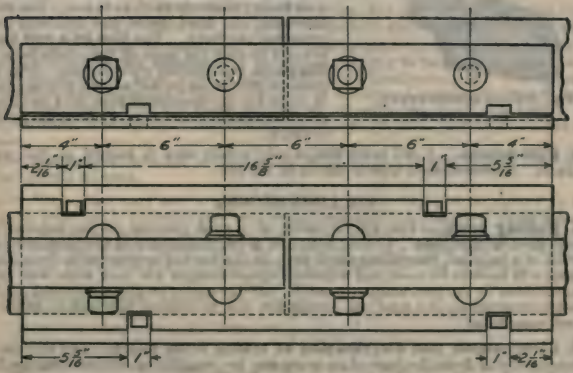


FIG. 115.

The railway staff officer in charge of each station must see that there is sufficient storage room for all railway purposes, so that under the most adverse circumstances there will be **no excuse for leaving material stored in cars.** Tents should be supplied for this purpose when buildings are not available or convenient.

199. **Roundhouses.**—At division terminals temporary roundhouses will be constructed, or storage tracks will be laid, for the proper cleaning and repairing of engines. The plan of such a roundhouse is shown in fig. 109. A **turntable** (fig. 110) is desirable at such points, but if the number of engines is not great, and no roundhouse is available, a few parallel tracks and a **Y** (fig. 94) for turning engines, will answer the purpose of a roundhouse with a turntable. Simplifications of the elaborate turntable shown in fig. 110 will suggest themselves to the engineer.

200. **Shops.**—At these same terminals would be located machine shops large enough to keep in repair all the locomotives that would be stabled in the roundhouse, and car repair shops large enough to make all necessary repairs to cars damaged on that division.

201. **Yards.**—At division terminals and at other large stations yards must be constructed large enough to receive all the cars entering the station and still allow room for the switching that is necessary in making up trains and in moving cars to and from the storage tracks. In addition, there will be the necessary number of passing tracks. All cars and trains moving in one direction should be handled on one side of the main track. Cars and trains moving in the opposite direction will be handled on the other side of the main track. This is probably the best arrangement feasible; but even when all the yard is on one side of the main line a certain part of the yard is assigned to switching and making up trains moving in one direction, while another part is allotted to traffic moving the opposite way. A very complete type of **terminal yard** is shown in fig. 111. Types of **division terminal yards** are shown in figs. 113, 114.

Local conditions will govern the exact location of yards and special tracks, and only general rules can be made in reference thereto.

A good and convenient form of siding, known as a **"lap siding,"** is shown in fig. 112. When two sidings are necessary and the space is available, this form is an excellent one; whichever train is waiting, or if two are waiting, the locomotives are both within a few steps of the station. Signals are given, and orders are transmitted with more convenience and certainty and less time is lost than if the two sidings were adjacent.

FIG. 116.—PRESSED-STEEL RAIL BRACE.

202. **Rail joints.**—A rail joint consists of a pair of **fish plates,** or **angle bars,** and from four to six **bolts.** The length of angle bar used to-day varies from 17 to 48 ins. The bolts alternate, one head inside and the next head outside of the track. The **ties at a rail joint** are laid so that the ends of the angle bars, or fish plates, rest directly over the ties. Fig. 115 shows a size of angle bar and an arrangement of bolts for the suspended joint that has given great satisfaction and is in general use in this country.

203. **Rail braces.**—A rail brace that is very widely used is known as the Ajax rail brace. A pressed-steel type is shown in fig. 116.

ROLLING STOCK.

204. **Rolling stock.**—The rolling stock of a road consists of the locomotives and cars used on that road. Unless notice is given in advance of the proposed construction of a railroad, the rolling stock then on the market or procurable from other railroads will have to be used, and whatever disadvantages are met with will have to be overcome in the best manner possible. If due notice be given, however, of the proposed construction of a road, an equipment can be ordered that will be suited to the local conditions.

205. **Composition and distribution of traffic from bases.**—The amount of traffic originating from the base of an army can be roughly calculated from the following data: From October 1, 1899, to October 31, 1900, there were transported from the three ports, Cape Town, East London, and Port Elizabeth, South Africa, approxi-

mately 200,000 men; for **each thousand of these men,** during this time, there were also transported 41 officers, 765 animals, 2 guns, 15 vehicles, and 1,406 long tons of stores and supplies.

A compilation for a longer length of time shows that from October, 1899, until June, 1901, from the same three ports, 287,571 men were moved, and that for **each thousand men** there were also transported 44 officers, 672 animals, 1.5 guns, 14.5 wagons, and 1,960 long tons of supplies and stores. From the port of Durban, 89,399 men were transported to the front from September 20, 1899, to June 30, 1901; for **each thousand of these men,** during this time, there were also transported 34.7 officers, 855 animals, 1.9 guns, 7.8 vehicles, and 3,624 long tons of stores and supplies. In addition to this and to the civil traffic that was permitted, from November, 1899, until June, 1901, the railroads moved 941,764 soldiers, 346,965 animals, 10,494 vehicles, and 389,066 long tons of stores and supplies, for which no average length of haul is given. The **percentages of carloads** of the various supplies originating at the bases were as follows: Supplies, 48.5%; ordnance and engineers' stores, 9%; troops, including animals and baggage, 25%; railway stores and labor, 1.5%; remounts, 14.5%; hospital trains and stores, 1.5%.

206. **Locomotives.**—On supply lines, the sharpest curve allowed would determine, in a measure, the gage to be used, as a much sharper curve can be used on a narrow-gage road than on a standard or broad gage road. Having decided upon the gage to be used, the first thing to be considered is the **tractive power** desired in the locomotives. A reference to the catalogues of the various firms that build locomotives will give all the data in reference to the ones built by those firms. The tractive power, T, is usually given in pounds and represents the pulling power of the locomotives on a clean, level track. Other conditions being equal, the tractive power of locomotives varies directly with the working steam pressure, the area of the piston, the length of the stroke, and inversely as the circumference of the drivers. It is limited to about ⅙ of the weight on the drivers, under favorable conditions, and to as low as ¼ of that weight on slippery track.

$$T = \frac{(\text{diam. piston})^2 \times \text{ave. steam pressure} \times \text{stroke}}{\text{diameter of drivers}} \text{ (ins. and lbs.).}$$

Not more than 80% of the theoretical tractive power should be counted upon in working a locomotive, as it has been found in railway practice that this is about the economical percentage to be used. The length of the rigid wheel base and the shape of the wheel should be noted to make sure that the engine can take the maximum curve of the road. The maximum weight on a single axle will determine the lightest rail that can be used for that locomotive (Table VIII, see par. 12).

The kind of grate will depend on whether wood or coal is to be used as fuel; only in exceptional circumstances would a wood burner be counted upon at the present day.

All locomotives should be equipped with the modern air brake.

Where the locomotives are to be built to order, the specifications should require that the boiler, water tank, cab, and other vulnerable parts should be **bullet-proof.**

The **speed of the locomotive,** under certain loads and grades, must be computed, and a **freight locomotive** should be required to have an average speed of about 15 miles per hour when hauling 80% of its maximum load. The speed of a locomotive and the hauling capacity should be considered together, for it is evident that a locomotive that will move 500 tons at 15 miles per hour can handle more freight than a locomotive that moves 600 tons at 10 miles per hour on the same grade.

For **passenger service** a locomotive with larger driving wheels and higher speed should be used.

207. With good cars and a good track 1 ton (2,000 lbs.) can be moved by about 6½ lbs. pull. It is probable that on a supply railway the **tractive resistance** per ton, F, would be considerably more than this; probably from 8 to 10 lbs. per ton. This, however, would depend upon the condition of the track and the condition of the rolling stock, and is given approximately by the following formulæ:

Engineering News formula, $F = 2 + \frac{V}{4}$,

American Locomotive Co. formula } $F = 3 + \frac{V}{6}$,
Baldwin Locomotive Co. formula }

in which F = tractive resistance in pounds per ton at a speed of V miles per hour on a level track.

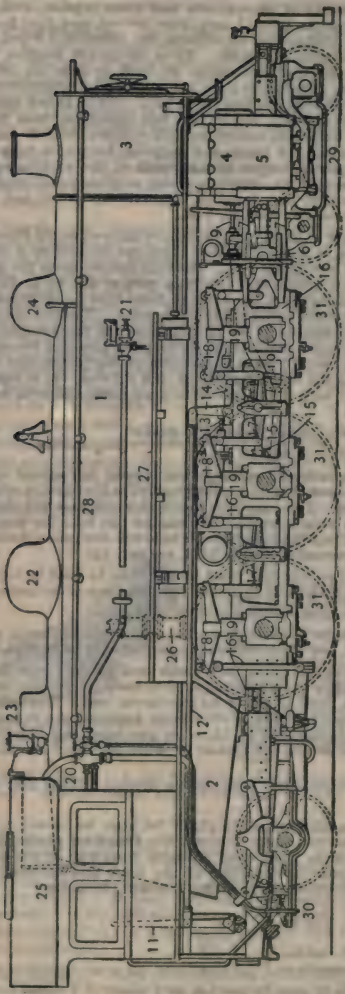


FIG. 117.

NOMENCLATURE OF PARTS OF LOCOMOTIVE.

1. Boiler.
2. Fire box.
3. Smoke box.
4. Steam chest.
5. Cylinder.
6. Crosshead.
7. Guides.
8. Piston rod.
9. Valve stem.
10. Link.
11. Reverse lever.
12. Reach rod.
13. Tumbling shaft.
14. Rocker arm.
15. Eccentric rod.
16. Frame.
17. Equalizing bars.
18. Springs.
19. Pedestals.
20. Injector.
21. Boiler check.
22. Steam drum.
23. Filling funnel.
24. Sand box.
25. Cab.
26. Air pump.
27. Footboard.
28. Hand rail.
29. Pilot truck.
30. Trailing truck.
31. Drivers.
32. Main rod.
33. Side rods.

The following paragraph shows how the hauling capacity of a locomotive is cut down by grades, and on this account the ruling grade should be kept as small as the conditions of construction will permit.

The **total force,** T, in pounds required to move W tons up a grade where the **grade resistance** is G lbs. per ton, and the force required to move 1 ton on the same track on the level is F lbs. per ton, is given by the formula

$$T = W\ (G + F)\ (G \text{ is not affected by speed}),$$

in which $G = 2000 \tan \theta$, when θ = angle of compensated slope (see par. 63). (Practically, G = 20 times the percentage of grade.) The weight of locomotive must be included in the train load in above formula. Inertia and wind resistance are not included in T.

Having decided upon the locomotives to be purchased, a table should be made showing their hauling capacity on various grades, and from this table and the division profiles can be determined what is known as the **tonnage rating** of the locomotive; that is, the number of tons that the locomotive will haul over the grades on the division where it is to be used. If different types of locomotives are used on the same division, the tonnage rating of each class should be determined and given to the chief dispatcher, in order that he may know the maximum load that should be required with each locomotive.

208. **Tenders.**—The capacity of the tender in fuel and water is determined by the local conditions, and since the establishment of pumping and coaling plants entails considerable time and labor, the tender should carry more fuel and water than would be desirable under commercial conditions. The capacity of tenders as shown in catalogues might be doubled.

209. **Number of locomotives.**—Knowing the amount of supplies to be carried by the railroad and the amount that can be handled in one train, the **number of locomotives** can be easily computed; but in providing locomotives provision must be made for a great many accidents, and the number of locomotives ordered should be about one and one-half times the number that it is expected to use at one time, thus allowing one-third of the whole number to be in the repair shop at one time.

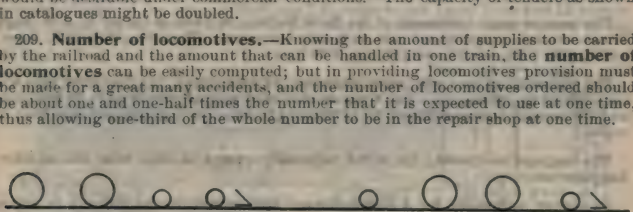


FIG. 118.—LOCOMOTIVE CLASSIFICATION.

210. **Interchangeable parts.**—Whatever kind of locomotive is purchased, the specifications should require that all the parts should be interchangeable in all locomotives of the same class.

Fig. 117 shows a locomotive with all parts numbered and named.

Locomotives are classed by the number and disposition of their wheels. The most common types and the names by which they are known are illustrated in Fig. 118, in which the larger circles represent drivers and the smaller ones truck wheels, the direction of forward motion being also indicated.

A better system, rapidly coming into use, is to describe the running gear by giving the no. of wheels in the three following groups in the order named: (1) **Forward non-drivers,** (2) **drivers,** and (3) **rear non-drivers.** Thus an engine with 2 forward truck wheels, 4 drivers, and 2 rear truck wheels is indicated by 2—4—2, etc.

By this system the Atlantic type becomes 4—4—2; the Columbia, 2—4—2, etc.

Locomotives are also classed as passenger and freight, the former having large drivers and other proportions adapted to high speed.

211. **Cars.**—In deciding upon the cars to be used on a supply railway, the gage of the track will almost entirely govern the kind of cars to be used. There is one rule that should be followed in purchasing or designing an equipment for such a road; that is, to have the **axle load** for loaded cars the same as that for locomotives whenever practicable. This will not be difficult for narrow-gage equipment, but on standard-gage roads the weight of some of the engines is so great that it is not economical to have the axle load of the cars equal to the axle load of the locomotives. If all axle loads were the same there would be considerable economy in cars, and the track would then be utilized to its greatest working value by every wheel that went over it.

212. **Passenger equipment.**—Passenger cars may be divided into day coaches, standard sleepers, tourist sleepers, dining cars, baggage cars, and kitchen cars. It will be impossible to obtain a narrow-gage passenger equipment in this country, except by special order with plenty of time for building the new equipment.

The narrow-gage equipment of the Barsi Railway in India is for a 2 ft. 6 in. gage. These cars are compartment cars with side entrances. Their length is 40 ft. 6 ins.; width, 6 ft. 2 ins. inside; weight, about 20 tons.

The second-class cars will carry, crowded, 64 passengers; the first-class cars will carry about 24 passengers. One train on this road carried comfortably 30 first-class and 736 second-class passengers in 13 cars. (Distance not stated, but less than 21 miles.)

The baggage cars would not differ materially, except in size, from the standard baggage car.

Passenger equipment for a standard-gage road would not be difficult to obtain from the various roads in this country, and in a foreign country such cars could be shipped from this country, or purchased from some neutral, or captured from the enemy.

213. **Day coaches.**—A standard day coach will carry about 60 persons, seating two in a seat. Unless there were an emergency, only three men would be put in a double seat, leaving the remaining room for the soldiers' equipment. About 45 men per car can be counted on by this arrangement. Whatever kind of coach is decided upon, the toilet arrangements and drinking supply should be ample for the car when fully loaded.

214. **Sleeping cars.**—A standard sleeper has about 15 sections counting the drawing room, and will carry, crowded, about 60 people. A tourist sleeper is similar to a standard sleeper, except in its appointments, and will carry about the same number of people. The remarks as to water supply and toilet arrangements with reference to coaches apply equally to sleepers.

215. **Baggage cars.**—Baggage cars are designed to carry about 150 pounds per passenger on the train. This will allow for rations for the men, as well as for their luggage. These cars should have end doors for communication while the train is in motion. **Kitchen cars** are baggage cars equipped for cooking.

216. **Freight equipment.**—The freight equipment of a road is of first importance, and in an emergency the troops can be moved in the freight equipment by arranging benches in the box cars, stock cars, and flat cars.

217. **Box cars** for narrow-gage roads would be similar in construction to, but smaller in dimensions than, those for a standard-gage road. Box cars on a 2 ft. 6 in.

railway can be built to carry 15 tons, and the carrying capacity varies from this up to 40 tons for a good standard-gage box car (see fig. 119).

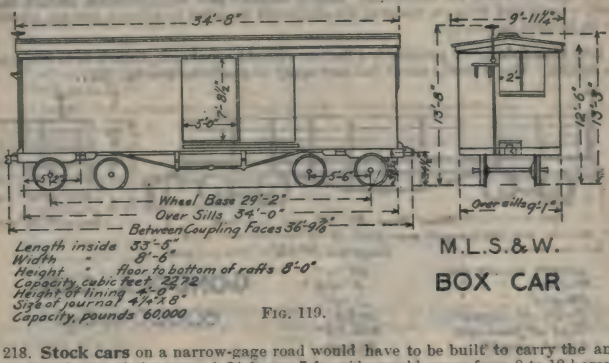


FIG. 119.

218. **Stock cars** on a narrow-gage road would have to be built to carry the animals lengthwise of the car. A 34-ft. car 7 ft. wide would carry from 8 to 12 horses. Padded **cross gates** would have to be put in to keep them from being injured by the

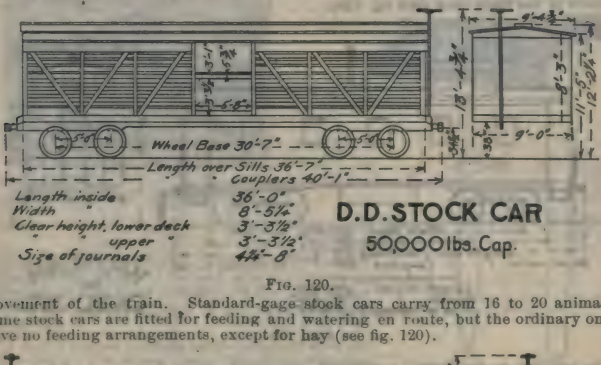


FIG. 120.

movement of the train. Standard-gage stock cars carry from 16 to 20 animals. Some stock cars are fitted for feeding and watering en route, but the ordinary ones have no feeding arrangements, except for hay (see fig. 120).

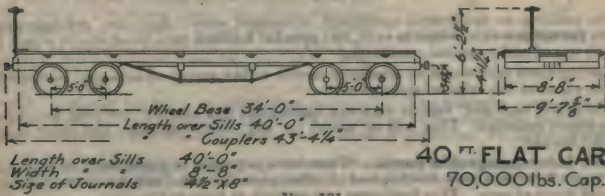


FIG. 121.

219. **Flat cars** are used for carrying heavy and bulky articles that will not be injured by exposure to the weather. The capacity of these cars varies from 15 or 20 tons on a 2 ft. 6 in. road to 60 tons on a standard-gage road. The average capacity of a standard-gage flat car is about 70,000 lbs. (see fig. 121).

By means of the platforms or ramps referred to in par. 561, guns and vehicles can easily be loaded on these cars. By removing the tongues and chocking the wheels, the vehicle is ready for shipment. Empty wagons and other vehicles should have both wheels and tongues removed for shipment in order to allow a greater number to be shipped on one car.

220. **Gondolas.**—A gondola is a flat car with sides and ends, from 2 ft. to 3 ft. 6 ins. in height. The remarks about flat cars apply to gondolas (see fig. 122).

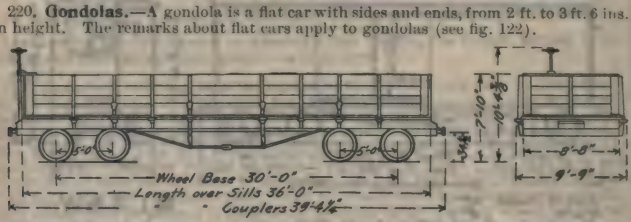


Fig. 122.

221. **Cabooses,** or **way cars** are cars for use with freight trains for the accomodation of the train crew (see fig. 123).

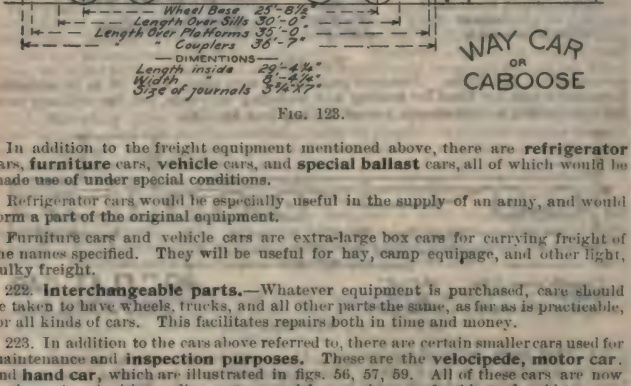


Fig. 123.

In addition to the freight equipment mentioned above, there are **refrigerator** cars, **furniture** cars, **vehicle** cars, and **special ballast** cars, all of which would be made use of under special conditions.

Refrigerator cars would be especially useful in the supply of an army, and would form a part of the original equipment.

Furniture cars and vehicle cars are extra-large box cars for carrying freight of the names specified. They will be useful for hay, camp equipage, and other light, bulky freight.

222. **Interchangeable parts.**—Whatever equipment is purchased, care should be taken to have wheels, trucks, and all other parts the same, as far as is practicable, for all kinds of cars. This facilitates repairs both in time and money.

223. In addition to the cars above referred to, there are certain smaller cars used for maintenance and **inspection purposes.** These are the **velocipede, motor car**, and **hand car,** which are illustrated in figs. 56, 57, 59. All of these cars are now made equipped with gasoline motors, and for speed are preferable to the old type.

224. **Track capacity.**—In figuring on the length of sidings, the length of the cars and locomotives must be known. These lengths for a 2 ft. 6 in. gage may be taken about as follows:

Locomotives, 50 ft.
Box cars, 30 ft.
Flat cars, 30 ft.
Passenger equipment, 45 ft.
Stock cars 34 ft.

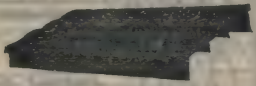
The length for a standard-gage road may be taken about as follows:

Locomotives, 65 ft.
Day coach, 60 ft.
Sleepers, 75 ft.
Baggage cars, 50 ft.
Box cars, 37 ft.
Furniture cars, 50 ft.
Flat cars, 44 ft.
Gondolas, 40 ft.
Refrigerator cars, 40 ft.
Cabooses, 40 ft.
Stock cars, 40.

Certain special cars will be longer than these lengths given; but in the general run of a train, taking all cars as they come, these lengths will give a fair estimate of the length of a train.

FIG. 124.—ELLIS BUMPING POST.

FIG. 125.—TIE PLATE.



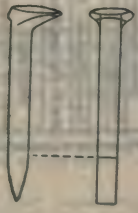


FIG. 126.—RAILROAD SPIKE.

225. **Buffers.**—A buffer, or bumping post, is an arrangement placed at the end of a spur track to prevent the cars from running off the end of the track. A commercial form of the same is shown in fig. 124.

A heavy timber chained across the track answers very well for a bumping post. One of the simplest and best means of ending a spur track is to dump a **pile of cinders** across the end of the track for about half a car length from the end, about 3 ft. thick.

226. **Ties.**—A tie for a standard-gage railway has a rectangular cross section of about 6 by 8 ins., and the length is 8 ft. White oak and cedar make the best ties, but on a military line any available timber will answer if spikes can be driven therein.

227. **Tie plates.**—On curves and bridges, tie plates can be used advantageously. These plates are usually of steel and prevent the rail from cutting into the tie (see fig. 125).

228. **Spikes.**—The commonest form of railway spike is shown in fig. 126. The weights of these for various sizes are shown in Table VI.

OPERATION AND MAINTENANCE.

229. Whether a road is constructed, or merely taken over, for military purposes makes no difference in the operation and maintenance of the line.

The **unit of organization** is the **division;** such a division is a section of line from 150 to 300 miles in length, and is self-contained. As to operation and maintenance, the general principles and rules are laid down by the higher authorities, but the details are left to the Division Superintendent to work out as he thinks best. The results show in the economy and efficiency of his division, which are the tests of the soundness of his methods.

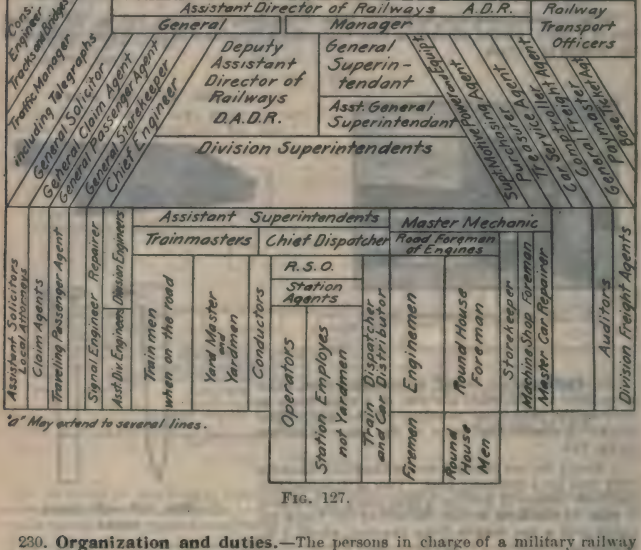


FIG. 127.

230. **Organization and duties.**—The persons in charge of a military railway can be divided into two classes: **Military controlling staff** and **civilian officials.** The military controlling staff will be chosen from engineer officers and others who have had railway experience, and their function is to make known the military desires and to see that the roads are operated so as to attain these ends. Having given their instructions, they allow the civilian officials and employees to work out the technical details in the manner dictated by their railway experience; the military staff will only interfere in cases where they believe that the civil officials are not endeavoring to carry out the military plans, or are not succeeding in doing so.

The organization and **line of responsibility** are shown in fig. 127.

The relation of the military controlling staff to the civilian officials is shown in that figure.

231. **Military railway staff.**—All railroads under military control must be under the direction of one head, known as the **Director of Railways** (D. R.). If there is only one theater of operations, this officer will be on the staff of the **General Commanding** (G. C.) in the field. If there are several theaters, his headquarters will be where he can best supervise the work of all the railways; and the railways in any particular theater will be under an assistant, known as the Director of Railways of that particular army; as, D. R., Army of Virginia.

232. **Duties of the Director of Railways and his staff.**—The duties of the D. R. of an army and his staff are, to operate the railroads so as to promote the plans of the G. C., to supply the military knowledge not possessed by the technical railway staff, and to shield the railway operatives and officials from unauthorized **military interference.**

The D. R. is responsible for all lines under his control. In a large field of operations there will ordinarily be several independent systems of railways. If several such systems are in one **Line of Communications** (L. of C.), they will all be controlled by a **Deputy Director of Railways** (D. D. R.), who sees to the cooperation of the several lines. He is on the staff of the **General Commanding the Line of Communications** (G. C. L. of C.), and the other military railway officers are subordinate to him. If only one system is in each L. of C., there will be no D. D. R. To each system will be assigned an **Assistant Director of Railways** (A. D. R.), and on each of the several systems are placed certain **Deputy Assistant Directors of Railways** (D. A. D. R.), each of whom has charge of one or two divisions of the line. The A. D. R. is on the staff of the G. C. L. of C., and the D. A. D. R. are assistants to him and therefore are members of the same staff (see fig. 127.)

233. **Duties of the D. R. of an army.**—This officer is responsible to the G. C. for the successful operation and cooperation of all the railroads in his charge. He receives his orders from the C. of S. and takes the necessary steps to have them executed by his subordinates. He must keep in close touch with his D. D. R. and A. D. R. and with the higher civil officials of all his railroads. He must know the capacity and condition of each line, and must make arrangements at home for the prompt and accurate filling of requisitions. He keeps direct control over the armored-train defense of the railways.

234. The D. D. R. will keep fully informed of the **condition** and **capacity** of the various systems under his control, and will so distribute the traffic that each road will be kept busy with its share of the work. He will keep track of rolling stock and will distribute it from one road to another as may be necessary. He will direct railway supplies to points most needful.

235. **The A. D. R.** may be called the **military manager** of the road to which he is assigned, the **civil manager** being his close adviser, and the person through whom he controls his civil employees. He is charged with the efficient operation of the line to which he is assigned, including its operation, maintenance, and supply, and he advises the D. R. as to its requirements for defense. He has charge of the **special railway police** on his line.

The **military controlling staff** will decide what affairs will be left entirely to the civilian officials and what ones must be referred to the coordinate military officer for final decision. The A. D. R. will decide the above points usually after consultation with his D. A. D. R.

236. **Civil traffic.**—The A. D. R. of any particular line, after consultation with the D. D. R. or the D. R., can authorize such civil traffic on his line as he thinks will not interfere with the military traffic.

Regulations for such traffic will be issued by the A. D. R. or the D. A. D. R., and only such traffic will be allowed as the rules cover. The **Railway Transport Officer** (R. T. O.) and the **Railway Staff Officer** (R. S. O.) will issue permits in conformance with these regulations only.

237. The D. A. D. R. are assigned one or more divisions of the line, depending upon the road, and they may be termed the **military superintendents** of such divisions. The **civil superintendents** are their close advisers. They are responsible to the A. D. R. for the efficient handling of their divisions. They supervise the R. S. O. on their divisions, and must be thoroughly conversant with the possibilities and needs of such divisions. They must keep track, through the car distributor, of all rolling stock, and if cars are not promptly unloaded and released, will call the R. S. O. at the detaining station to account for it. They must correct all weaknesses in their divisions, or call upon higher authority to do so. They are responsible for the maintenance and the regular military police of their divisions, and for the

transportation of troops and supplies within the limits of their divisions. They are responsible that the various stations have the proper sidings, platforms, ramps, stockyards, and watering facilities to fill the military requirements.

238. **Railway transport officer.**—At each of the bases from which military roads are operated there will be detailed a Railway Transport Officer (R. T. O.), who will be on the staff of the D. D. R. (or A. D. R. if there is no D. D. R.). This officer's duties will be, first, to make arrangements with the railway officials for all transportation of troops, animals, supplies, etc.; second, to attend to the loading and unloading of troops and animals at the base; third, to issue transportation from the base for all officers and soldiers not traveling on troop trains; fourth, to issue permits for and regulate all nonmilitary transportation; fifth, to pay all railway accounts on receipt of the proper vouchers; sixth, to pay all civilian labor employed on the military railways.

239. **The R. T. O.** will be notified of the expected arrival of troops, animals, or supplies, and will promptly confer with the D. D. R. or the A. D. R. as to the best route to be followed by the troops, animals, and supplies. This officer should be of the Quartermaster's Department.

240. At each **important station** there will be detailed a Railway Staff Officer (R. S. O.), who will be independent of the C. O. of any troops that may be stationed at that point, and will be on the staff of the A. D. R.

241. The R. S. O. of stations look after the loading and unloading of troops and supplies at their stations. They keep the D. A. D. R. fully informed as to all the **station requirements.** They are in charge of all railway employees while at that station, and will execute such authority, as a general rule, through the local station agent. They issue, on proper authority, **all transportation** from their stations, and forward with their indorsement **all communications** from the local officers to the railway officials. They are responsible that all cars are promptly unloaded and released, and that no empty cars are asked to be sent to their stations before the cargo will be ready for loading. They make arrangements for **food and hot coffee** for troops en route through their station, upon notification from proper authority.

242. The R. S. O. reports daily, to the D. A. D. R. of his division, the organizations or parts of organizations that depart from or arrive at his station, and includes the following data: Destination, or starting point; the number of officers, men, guns, horses, vehicles, and the amount of supplies in each train; the number of the train, and the time of its departure or arrival.

The D. A. D. R. consolidates all these reports for each week, and renders this **consolidated report** to the A. D. R., with such other information with reference to the movements as may be desired.

243. **Detaining cars.**—The history of the **Civil War** and the war in **South Africa** both emphasize strongly the necessity for the most stringent orders with reference to the **prompt unloading of cars.** The R. S. O. is authorized to call on the C. O. of the station for the necessary details to unload the cars immediately upon their arrival. If for any reason he can not get such details, or can not unload the cars inside of 48 hours, he will report the facts to the D. A. D. R. by telegraph.

244. **Troop movements.**—When an order for the movement of troops from any station is received at the station, the R. S. O. will immediately find out the following points with reference to the proposed movement from his station:

(1) The number of men and officers.
(2) The number of animals.
(3) The number of wagons, guns, etc.
(4) The amount of supplies that will be carried with the troops.
(5) The destination of such troops.
(6) The time of departure.

He will immediately forward this information by telegraph to the D. A. D. R., with such other information with reference to the movement as he may think necessary.

245. The R. S. O. is responsible that no **railway buildings** or **property** are used by the troops at the station, when necessary for railway use; and before permission is given for such military use, authority will be obtained from the D. A. D. R.

Upon the **arrival of troop trains,** the R. S. O. will be present and give the C. O. on the train all information and proper assistance that he is able to give.

At stations where there is no R. S. O., the C. O. of the station will carry out the military duties, and the station agent performs the railway duties of the R. S. O.

246. **Civil officials.**—On a road operated for military purposes, the head official is the **general manager.** The president, vice-president, etc., are temporarily replaced by the higher military officers. The **general manager** is responsible for the entire working of the road and for all maintenance and construction thereon. He has the number of assistants necessary to relieve him of all minor details and leave him free to keep a keen oversight of the entire working of the road.

Fig. 127 shows the various other officials who report to him.

247. The next official in rank to the general manager and his assistants is the **general superintendent,** who has charge of the operation, maintenance, and discipline of the road, the arrangement of time schedules, the distribution of motive power, and such other duties as may be assigned to him by the general manager. He has such assistants as may be necessary.

248. The **general solicitor** of the road is the legal adviser of the general manager, and even in time of war there would be many occasions on which this official would be necessary. He has the necessary number of assistants, and all **local attorneys** for the road report to him.

249. The **general claim agent** has charge of all **claims** made against the road for damages. He investigates all such claims, procures all available information and witnesses to defend the case, and recommends the action to be taken.

250. The **general passenger agent** in time of peace is charged with the duty of procuring all passenger business that he can for the road. **In time of war** this duty would lapse, but he would be utilized in connection with the shipment of troops and the handling of passenger traffic generally.

251. The **general storekeeper** has charge of and issues all stores from the central storehouse. He keeps a supply of stores that will meet all possible needs of the road. The storekeepers at various points on the railroad make requisitions on him through the general manager and render their returns to him.

252. The **chief engineer** of the road is the engineer adviser to the general manager. He plans and has charge of all new construction, and he keeps a general oversight of the division engineers and the signal engineer. He has no control over the construction work on the **field divisions.**

253. The **superintendent of motive power and equipment** has charge of all the rolling stock belonging to the road. He is charged with all repairs to locomotives, machinery, cars, and other equipment. He investigates all **failures of engines.** He keeps complete **records of performances** of locomotives and cars. He has charge of the discipline of all his employees, except enginemen and firemen who may violate operating department rules while on the road.

254. The **purchasing agent** of the road buys all supplies, equipment, etc., that may be used on the road, upon authorization of the general manager.

255. The **treasurer** is responsible for all funds received for operating the road and for the disbursement of all moneys.

256. The **comptroller** has the final decision as to the correctness of expenditures and accounts, and he allows or disallows accounts according to their merits and the rules of the road. The treasurer and comptroller would be used to keep the account between the railway and the Government while the road is under military control.

257. The **general freight agent** of the road in time of war would have few of the duties that this official has in time of peace, but he will be useful to the general manager in the **handling of military freight.**

258. The **signal engineer** is under the chief engineer. He has charge of construction and maintenance of all **signals and telegraphs** and other work requiring electrical knowledge.

259. The **car-service agent** is charged with the proper distribution of rolling stock to the various parts of the road. He keeps track of all cars sent to foreign roads, the mileage of all cars on the road, and the length of time that foreign cars are held on the road.

260. **Duties of division superintendents.**—The road will be divided into divisions, and each division is in general charge of a **division superintendent.** These superintendents are directly under the general superintendent and his assistants. They have complete charge of their divisions, and are responsible to the general superintendent and general manager for the proper operation and maintenance of their divisions. **Matters of construction** that come under the division engineer are not under the division superintendent, and the subject of **repairs to rolling stock and equipment** is handled by the master mechanic direct with the superintendent of motive power and equipment and is not under the division superintendent.

The division superintendent is assisted in his work by one or more **assistant superintendents, division engineers, and master mechanics.**

261. Each **assistant superintendent** is charged with such duties as the superintendent may assign to him. In general, the division will be divided and each assistant superintendent will have charge of one such subdivision. He handles all train movements and has charge of trainmen, agents, and operators. He is charged with the **discipline** of these men and with that of employees in the master mechanic's department for the violation of operating-department rules.

262. Each **division engineer** is charged with all maintenance and construction work on his division. For **maintenance** he is responsible to the superintendent, and for **construction work** to the chief engineer of the road.

The division engineer has the necessary number of assistants, and in general, the work under his office will be subdivided into **bridges and buildings, track work, masonry work, and water supply.** Each of these departments will be under a competent foreman, who will have charge of the tools and supplies necessary to carry out his work on the division. A fuller description of his department will be found under "Maintenance of Way," par. 532 et seq.

263. Each **master mechanic** is charged with the **inspection and repair** of all rolling stock. In all matters aside from the operating-department rules, the enginemen and firemen are directly under him. He has charge of the inspection department and of all roundhouses, machine shops, car shops, storehouses, etc., and the employees therein are under his orders. For all subjects that arise in his department on the road, he is responsible to the superintendent. Aside from this, he is under the direct supervision of the superintendent of motive power and equipment. He is responsible that all locomotives are in condition to haul their **tonnage rating** (par. 207).

The master mechanic is assisted in his work by one or more **traveling engineers,** who look after the proper handling of the locomotives on his division and investigate accidents and failures that occur on the road.

Each roundhouse and shop is in charge of a foreman, who is responsible for the discipline of the shop and the employment of the necessary workmen, etc.

264. The **storekeepers** at various points are under the master mechanic. They issue supplies on requisitions signed by any division officer, and in an emergency will issue supplies direct, without the necessary approval, taking the proper receipts for the same.

265. The **assistant superintendents** are assisted by the necessary number of **train masters** and **dispatchers.** The **train masters** travel over their divisions and look after the movement of trains and the actions of trainmen and yardmen. They accompany all important shipments or movements of freight or troops over their divisions, and see that the movements take place promptly and properly. They recommend any discipline that may be necessary, and can issue orders for trains when they think necessary. They are directly under the assistant superintendent, but can receive orders from any higher officials. They give special attention to the prompt and regular movement of traffic and see that the full number of cars are moved by each locomotive, and that no more trains are run than are necessary. They inspect and report on the cleanliness of the passenger trains, and investigate delays in trains, as well as delays in loading and unloading of cars. In **case of an accident,** they proceed to the scene of the accident and take general charge in clearing up the road and protecting the wrecked property. They perform such other duties as may be assigned to them by the proper authority.

266. The **chief dispatcher** has entire charge of the movement of trains over his division, unless the train master interferes for some special reason. He distributes the cars and motive power; he places and displaces operators and subordinate dispatchers, subject to the approval of the division superintendent and of the signal engineer. He has charge of all telegraph matters and movement of trains by

telegraph over his division. He sees that all train orders are issued according to prescribed forms, and gives special attention to the condition of the telegraph equipment on his division. He sees that only one person issues train orders over any territory at one time. He is responsible that all locomotives are worked up to their full tonnage rating (par. 207).

267. **Train dispatchers** receive their instructions from the chief train dispatcher. They are assigned to certain subdivisions and issue orders governing the movement of trains over such subdivisions. They see that such orders are properly transmitted and recorded. They keep a record of the movement of all trains, or locomotives, over their subdivisions. They order the necessary number of locomotives in time to be ready to move when the train is made up. **Train orders** and **locomotive orders** are kept separate. One dispatcher keeps a book showing the **telegraphic address** of every official and lineman that may be out of his office working along the division, so that they may be found if needed. On **double-track work,** the dispatcher's main duty is to see that the trains are kept moving, and that no unnecessary delays occur. On **single-track work,** the position of train dispatcher is much more important than on double-track work, on account of the constant danger from collision in case of carelessness. He arranges the proper **meeting** and **passing** places for all trains, and in case one train is late, changes the meeting places to correspond. On going off duty, he makes a transfer of all orders that have not been fully executed, and sees that such orders are understood by his successor.

268. **Car distributor.**—One operator in the chief dispatcher's office is assigned the duty of distributing cars. He receives the **daily telegraph report** from each station (par. 270), and arranges the information for the chief dispatcher for use as described in par. 501. In this distribution of cars, due attention should be given to empties; otherwise, a car famine may exist at one point on the line, while the road may be blocked with empties at another point. To avoid this and keep the entire line properly provided with the kind of cars needed, the chief dispatcher makes a daily report to the car-service agent at headquarters, similar to the one described in par. 270. Car-service agents, at headquarters, on receiving these telegraph reports from the various chief dispatchers, distribute cars over the entire line just as the chief dispatcher distributes cars over his division. This report includes passenger as well as freight equipment.

269. **Station agents** are directly under the assistant superintendent and train masters. They have general charge of all station work. They are responsible for the condition of the station, the prompt placing of cars for loading and unloading, and for the proper arrangements for safety and comfort at the stations. They see that the ticket office is kept open at the proper time and that **tickets** are issued only on proper authority and to proper persons. They are responsible that the necessary **signals** are displayed. They are responsible that the track within the limits of their station is in good condition and that the proper switch signals are set. They see that the correct time, time-tables, and official notices are displayed in the depot. They inspect loaded cars, and when satisfied that they are loaded as indicated, they seal the car for shipment. They see that cars are not **overloaded** and that they are **properly loaded.** When cars are received, they promptly notify the persons to whom they are billed, and see that the cars are **promptly placed for unloading.** They will not allow any unauthorized persons to hang about the station, nor near the telegraph office, and they will see that all station employees do their duty properly. They will comply with all instructions from the R. S. O. of the station.

270. **Daily telegraphic car report.**—Before 8 o'clock in the morning, the agent at each station shall report, daily, to the chief dispatcher the following information with reference to freight equipment:

Local cars:

(1) *Number of empties wanted.* State kind and size, destination, loading, and when wanted.
(2) *Number of empties on hand.* State kind and size.
(3) *Cars to unload.* State kind and size (O. H. 24 hours or less).
(4) *Cars to unload.* State kind and size (O. H. 24 to 48 hours).
(Special report for all cars O. H. loaded over 48 hours.)

Foreign cars:

(1) *Number of cars wanted.* State kind, size, destination, and when wanted.
(2) *Number of empties on hand.* State kind, initials, number, and size.
(3) *Cars to unload.* State kind, initials, number, and size (O. H. 24 hours or less).
(4) *Cars to unload.* State kind, initials, number, and size (O. H. 24 to 48 hours).
(Special report for any car O. H. loaded over 48 hours.)

Cars ready to move:

(1) *State number of loads and empties.*
(2) *Cars ready to move over 24 hours.* **State number of loads and empties.**

The weather report, amount of water in tank, and coal report will be sent in at the same time.

This daily telegraphic car report will be formed into a large blank. The various headings and subheadings across the top will be numbered, and the subheadings lettered down the side of the form, so as to form a code that the operators can use in making this report.

On receipt of this information from all points on his division, the chief dispatcher is able to distribute the required empties and arrange to pick up all loaded cars.

271. Where there is no R. S. O., the **station agent** performs the railway duties of that officer, and the **commanding officer** of the troops at that station performs his military duties. At **larger stations,** the station agent is assisted by a station master in charge of the station and grounds, and by a ticket agent and such other employees as may be necessary.

272. At **terminals** and at **large stations** the **yard work** is in charge of a **yardmaster.** Yardmasters are directly responsible to the station agents and to the train master. They have charge of the employment of yardmen, the movement of trains and engines, and the distribution of cars in the yard under their charge. They see that all trainmen are called for duty on time, and that they report in condition for work. They have charge of the making up of all trains and the distribution of cars in the yards to facilitate the making up of trains. They are responsible that the trains leave on time and that the proper slips, or waybills, accompany each car. They see that all cars are properly secured and keep a record of the **car seals.** They keep a record of the cars received and delivered to other lines; they see that cars are properly placed for loading and unloading, and that all cars needing repairs are sent to the repair tracks or to the shops.

273. **Passenger conductors** report to and receive their orders from the assistant superintendent, and will obey the instructions of the train master. At terminals they will comply with the orders of the station agent and yardmaster. They are responsible for the movement, safety, and care of their trains, and for the vigilance and conduct of the train crews.

274. Every conductor will **compare time** with his engineman before starting on his run.

275. He will allow no person to travel on the train except when showing proper authority. If any person, having no authority for travel, boards the train, he will be put off at the next stop and turned over to the military authorities at that point. To put such persons off the train, the conductor can call on any officer or soldier to assist him.

276. The conductor will ascertain, when the train starts, who is the **ranking officer** on the train and will look to him for assistance in case of **disorder.**

277. He will see that all regulations in regard to stops, signals, safety precautions, etc., are obeyed at all times.

In **case of any accident,** he will make special report by telegraph to the division superintendent.

He is responsible for the running of the train, and all other members of the train crew are subordinate to him.

278. Each **passenger conductor** at the end of his run makes out a **report** showing his train number, the time of departure from and arrival at division terminals, engine number, name of engineman, and initial, number, and kind of all cars taken, and the names of the crew serving on the train, and any matter of importance that may have come up during his run.

279. Each passenger coach and baggage car will be supplied with the following **tools.** Conductors will be required to check the list on taking over cars.

Tools for coaches.

1 ax.
1 saw.
2 fire pails.
1 sledge.
1 cold chisel.
4 hand grenades.

Tools for baggage cars.

1 tool box.
1 switch cable.
2 frogs.
1 jack.
1 jack lever.
1 sledge.
1 ax.
1 steel bar.
2 brasses.
1 pail of dope.
1 train line hose.
1 air-signal hose.
1 chain.
1 saw.
1 cold chisel.
4 hand grenades.

IN WINTER.

2 scoop shovels.
1 or 2 barrels of coal.
1 track shovel.
1 pail of salt.
1 stove shaker.
1 fire shovel.
1 steam-heat hose.

280. **Train baggagemen** receive all baggage, mail, and express from the station baggageman, and will not carry goods of any sort except those received from this source. They will see that all baggage is put off at the proper stations. They are responsible for the mail when carried in the baggage car. They will give receipts for baggage received, and take receipts for baggage delivered to the succeeding baggagemen.

281. **Station baggagemen** will issue checks for baggage received from passengers traveling on the road on presentation of proper tickets. The amount to be carried on one ticket will be determined by the A. D. R. Baggagemen will see that no **excess baggage** is allowed, except as provided by regulations. They will receive and forward all mail. They will record all baggage checks issued and received. At the smaller stations these duties are performed by the station agents.

282. **Passenger trainmen** are under the orders of the conductor while on the train. They will see that the water tanks are kept filled with water, and that the lights, whistle signals, air brakes, steam heat, etc., are all in good working order. When necessary, in order to avoid delay, they will assist the baggagemen. In **case of accident,** they will act as flagmen under the direction of the conductor. They will notify the passengers of the name of each station before the train arrives at the station.

283. **Freight conductors** report to and receive their orders from the train master, and in stations from the station agent or yardmaster.

They will report to the operator of the station for orders before leaving the station, and will **compare time** with the engineman before starting from the initial station.

284. Every conductor will **inspect his train** before starting out, to see that all parts are in good order and that the proper signals are displayed.

He repeats this inspection whenever opportunity offers during the trip.

He is responsible for the movement, safety, and proper care of the train and for the vigilance and conduct of the other trainmen.

285. He must have **proper authority** in slips, or waybills, for the movement of each car in the train.

He will make out the **consist** or **detail sheet** referred to in par. 501, and will forward same to chief dispatcher by telegraph before leaving initial station.

286. **Passengers** will be carried **on freight trains** only when showing proper authority to travel on that class of trains.

287. He will card all **cars found defective** between terminals, noting the defect thereon. If the condition of the car permits, he will carry it to the next repair station; if not, the car will be set out at the next station and the slip, or waybill, left with that station agent or with the next nearest station agent. If the car is only partially loaded, he may transfer the load to another partially loaded car.

When **transferring freight** from one car to another, he will record the transfer on the face of the original waybill, together with the number of the car to which it was transferred.

He will carefully **check** with the waybills all **freight loaded** and **unloaded**, and will make a record of freight "over," "short," or in bad order.

288. He will see that all cars equipped with air brakes are placed next the locomotive, and that the air is used on all of them.

Cars carrying **oil** or **explosives** will not be carried next to the locomotive nor next to the caboose, and should be six cars from either one if practicable.

He will have **empty flat cars** placed on the rear of the train next to the caboose.

289. He will require all trainmen to read the orders received.

290. He will see that the brakes are set on all cars left on sidings.

291. On arriving at a station, he will have the necessary switching done and will replace any cars that may have been moved in doing the switching.

292. He will decide on the **number of cars** to be taken or left at any station, and if the engineman refuses to obey the orders, he will report the facts by telegraph to the assistant superintendent.

293. He will see that all trainmen are in position to perform their duties at least a mile before reaching any probable stop. In **case of accident**, he will send a brakeman to act as flagman, and will see that such brakeman understands his duty.

294. He will not take cars that are **improperly loaded** or **too heavily loaded**, and he will report such refusal to the assistant superintendent by wire.

295. In **case of accident** or **injury**, he will comply with par. 277.

296. He will make a **switching list**, showing the date and train number, and the initial, kind, destination, and contents of each car, and he will deliver this switching list to the terminal yardmaster at the end of his run.

297. Each conductor will keep a **train book**, in which he will record the date, number of his train, and number of locomotive. For each car he will keep record of initials, loaded or empty, where billed from and where billed to, where taken and where left, and the contents and weight.

The conductor will note in his train book the **seal on each door** of each loaded car in his train; and whenever a car is opened, a record of the **new seal** is made by him after the car is resealed. He will inspect all empties left at stations to see that no freight remains therein.

298. **Tools for caboose cars.**—Each caboose car must be supplied with the following tools, and conductors are required to check them over on receiving cars at terminals and junction stations, on taking their train at starting point, and on leaving it at destination, reporting all shortage and damage:

1 ax.
6 brasses.
1 broom.
1 dope pail.
2 markers.
1 cooler.
2 2-gal. oil cans, filled.
2 fillers.
4 chains.
1 chisel.
1 dipper.
1 washdish.
3 red flags, mounted.
3 white flags, mounted.
2 green flags, mounted.
1 pair of frogs.
1 hammer.
1 coal hod and shovel.
1 packing hook.
1 packing iron.
1 jack and lever (Barrett, No. 8).
3 red lamps, complete.
5 white lamps, complete.
1 water pail.
1 switch cable.
1 saw.
3 scoop shovels (in winter).
12 torpedoes.
1 lamp trimmer.
1 18-in. monkey wrench.
3 lbs. of waste.
2 packages of wicks, long and short.
1 package of matches.
1 package of tripoli.
1 package of lye.
1 mop and handle.
2 air hose.
1 indicator lamp.
1 set of indicators.
1 cupola lamp.
6 fusees.
1 Chicago knuckle.
1 Janney knuckle.

299. **Freight brakemen** receive their orders from the conductor while on the train. When acting as flagmen, they will compare their watches with the conductor before leaving him. As flagmen, it is their duty to **protect the train** in accordance with the rules, and they must allow nothing to interfere with them in this duty. They will not return to the train until signaled for by the engineman, and before returning will leave torpedoes or fusees according to instructions received.

300. **Enginemen** are under the orders of the assistant superintendent while on the road. In all matters relating to the care and use of their engines they are responsible to the master mechanic, and to the roundhouse foreman while in the roundhouse.

They will obey all instructions of the yardmaster as to shifting and making up of trains, and of the conductors of their trains as to stopping and starting, the general management of the train, the number of cars to take or leave, etc., unless such orders endanger the safety of the train or require a violation of the rules.

301. The engineman is **jointly and equally responsible** with the conductor for the safety of the train and the movement of the same in compliance with the rules. Before leaving the roundhouse, every engineman will **inspect his locomotive** and see that it is in good working order, furnished with the necessary supplies, sfores, signals, and tools, and he will report any fault that he may find.

302. He will **compare time** with the conductor before starting.

303. He will keep in the locomotive cab at night a lighted red lantern, with three torpedoes attached, for use in case of necessity.

304. He will report by telegraph any switch or signal not properly lighted or set.

305. He will be careful **not to dump ashes on wooden bridges or trestles.**

306. Before starting the train from the terminal, he will apply the air brakes and steam heat (if provided) and see that they are in perfect **working condition.**

The same will apply when new cars are taken into the train. He must know at all times that the air brake and air signal are in working order.

He will **test the air brakes** at least 1 mile before reaching a railroad crossing, a drawbridge, or a station. In case the **air brakes do not work,** he will promptly whistle for brakes. Brakes will not be applied while the train is crossing a bridge or trestle except in an emergency.

The engineman will look back frequently to assure himself that his train has not parted.

307. He will show the train orders to the fireman, so that the latter may know the orders in case the engineman is disabled.

308. He will **not leave his locomotive** while on duty except in case of necessity, and will then leave some responsible person in charge.

309. At watering and coaling stations the engineman will assure himself that he has **water and coal enough** to carry him to the next watering or coaling station; and if not, will take a proper supply.

310. He will not allow anyone to ride in the locomotive without a written order from the proper authority.

311. He will see that proper signals are made to give warning of the approach of the train.

312. Before turning the locomotive into the roundhouse at the terminal, he will **inspect it thoroughly** and report every fault that he may find in it, and will have it thoroughly cleaned above the running board.

313. The engineman is responsible for obeying all signals given him by the trainmen, for the proper observance of all station signals, semaphores, fusees, and flags, and in case of a stop signal, will at once notify the conductor.

314. **Tools for locomotives.**—Each locomotive in service is required to carry at all times the following tools, and enginemen must know that they have them and will be held responsible for any loss or deficiency:

1 cast-steel hammer.
1 12-in. monkey wrench.
1 18-in. monkey wrench.
1 18-in. eccentric set-screw wrench.
1 rod set-screw wrench.
1 air-pump combination box, and spanner wrench to suit size of pump.
1 hose wrench, for engines equipped with hexagon nuts.
1 8-in. cold chisel.
1 8-in. cape chisel.
1 18-in. set chisel.
1 drift, for disconnecting valve stems.
1 valve-stem clamp.
1 pinch bar.
1 clinker bar.
1 flue-plug bar.
1 ash hoe.
1 steel coal hammer.
1 scoop shovel.
1 broom.
1 iron water pail.
1 packing iron.
1 packing hook.
1 clinker hook (length to suit fire box).
1 supply of oak blocking.
1 assortment of bolts and nuts.
1 wrench for crank-pin and crosshead-pin nuts.

315. **Firemen** are under orders of the enginemen, and will obey them as to the work to be done and the manner of doing it.

The fireman will take charge of the locomotive in the absence of the engineman, and will not leave it until the engineman returns.

He will **not run the locomotive** in the absence of the engineman unless instructed to do so by the conductor.

316. In **case of accident** to the engineman, the fireman will stop the engine and report to the conductor, except in case of an attack on the train, in which case he will make the report after such attack has ceased.

317. **Telegraph operators** report to and receive their orders from the chief train dispatcher, and will comply with instructions from the signal engineer, station master, and other superior officers.

318. They will be constantly on duty during prescribed hours.

319. They will notify relieving operators, in writing, upon going off duty, of all orders to be delivered or of any unfinished business.

320. Day offices **must not be closed** for the night until "GN" is given by the train dispatcher. Before leaving, a card must be placed in the window, which can be **read from the outside,** showing where the operator can be found.

321. Where both day and night operators are employed, one will not leave the office until relieved by the other.

322. The operator will always keep a **red signal** and **torpedoes** close at hand for use in case of emergency.

He will receive, record, and transmit all orders governing the movement of trains, according to the prescribed forms and rules.

He will keep a **register of arrivals** and **departures** of all trains, and report same to train dispatcher immediately.

323. In transmitting messages he will give the individual signal before the first and after the last message; in receiving he will give individual signal at the time "O. K." is given, unless called for sooner by sending operator. The receiving time, together with the above signals, must be recorded on all messages.

324. Only such messages as pertain to the **operation of the railway** will be received and transmitted by the operator, except under special instructions that may be issued by the A. D. R. with reference to military messages and to messages from officers and civilians.

325. **Messages** sent by telegraph are **strictly confidential.** The telegraph office will be kept strictly private. No persons will be allowed in the office except employees, and **no loafing** will be permitted within hearing of the telegraph office.

326. No operator will take his batteries or instruments apart or alter the wires, tables, etc., without permission from proper authority.

Operators will make such wire connection and tests as may be directed by the higher officials to insure the proper working of all the apparatus; **one wire** will always be kept open, however, for instructions. They will promptly report any difficulty or break.

327. **Sending operators** must regulate speed of transmitting a message to suit the ability of the receiving operator. Under ordinary circumstances, the sending operator will be held **responsible for errors** in transmission.

328. Operators will sign their own office call after every third call. When an operator has called an office **nine times** he will yield to any other office wanting the circuit.

329. An operator sending to an office can **retain the circuit** by saying "HR" after the signature to a message before signing his office call. The key must not be thrown open to hold the circuit.

330. **Unnecessary communication** by wire between operators is forbidden.

331. No operator will **change his personal signal** without permission from the chief train dispatcher or other person in charge of operators on the division.

332. Whenever railway operators handle military or private business, they will be held responsible for the proper performance of their duty in this respect.

333. Operators and dispatchers are authorized to use the following **calls and abbreviations:**

Telegraph numerals.

1.....Wait a minute.
3.....Give me correct time.
4.....Where shall I repeat from?
5.....Close your key; you are breaking.
7.....I have business; are you ready?
8.....Busy on other wire.
9.....To clear the line for train orders, and for operators to ask for train orders; on division, wire will have preference over all signals excepting "21."
12.....See par. 441.
13.....See par. 442.
14.....What is the weather?
15.....Have you any orders?
16.....Dispatcher's freight report.
17.....Daily weather report.
18.....What is the matter?
19.....Train order, as provided in par. 438; or call for same.
21.....Extreme emergency; on division wire this must have preference over all other business; on through wire will have preference over signals "25" and "34."
23.....The following is for you and others.
24.....Repeat this back.
25.....Time reports of passenger and troop trains to general superintendent (used on through wire); preference of circuit over ordinary and "34" business.
28.....Do you get my writing?
29.....This is private and must be delivered in sealed envelopes.
31.....Train order, as provided in par. 438; or call for same.
34.....This message is of great importance.
39.....This must have preference over all other business on all wires, and will be used *only* by the G. C. and C. of S. of army or of L. of C., the D. R., D. D. R., and A. D. R.
41.....This will have preference over all calls on through wires except 39, and will be used only by general manager, general superintendent, and chief engineer.
92.....This message should be copied in ink.

NOTE.—Operators must not make use of any signals for business other than that to which such signals are assigned. In other words, signals must **not be given**

falsely; as, for instance, making use of "39" for "34" business in order to obtain the wire.

C. & E.—Conductor and engineman.
X——I have displayed my train order signal, and train will be held until order is made complete.
H. R.—I wish to hold the circuit.
O. K.—Complete.
O. S.—Train report.
No.—Number.
Eng.—Engine (locomotive).
Sec.—Section.
Pasgr.—Passenger.
Frt.—Freight.
Mins.—Minutes.
Jct.—Junction.
Dispr.—Train dispatcher.
Opr.—Operator.
S. D.—Stop displayed.
Usual abbreviations for months and stations.
Initials for signatures of division officials, office calls, and other signals authorized by chief dispatcher.

334. **Inspection of rolling stock.**—The inspection department is directly under the master mechanic, and is divided into two parts, inspection of cars and inspection of locomotives. Certain points along the line are indicated as **inspection points for cars,** and all cars entering such stations are inspected to see that all parts are in proper condition. The wheels are tested by a blow with a hammer to discover defects. At these inspection points cars are marked "O. K." if in good shape, and "B. O." if in bad order, and the initials of the inspector are written below to show who made the inspection. "Bad-order" cars are forwarded to the nearest car-repair station, if practicable; if not, they are set out (their loads may be transferred) and car repairers sent to repair them at that point.

These car inspectors are usually also oilers, and they see that the boxes are properly filled with waste and properly oiled.

335. In **oiling cars,** the oiler should be careful to get the waste packed well under the journal and in contact with the bottom of the journal. They must not get the boxes too full, as this is a fruitful source of **hot boxes.**

336. **Locomotives are inspected** on their arrival at the roundhouse by regular locomotive inspectors. They go over the locomotive thoroughly and submit a separate report on each. This report is **compared** with the report made by the engineman on the completion of his run, and each is held responsible for a defect reported by the other that is not shown in his report.

This method of inspection of locomotives is especially effective when the power is pooled. **Power is** known as "**pooled**" when no certain locomotive is assigned to one engineman, but the locomotives are run out of the roundhouse in the order of their coming in. An engineman needs from eight to ten hours' rest after a run, whereas a locomotive, if in good order, can be made ready for another run inside of a couple of hours. In addition to this saving of power, it has been found that the locomotives are in better shape on account of the report required by the engineman and the **check report** made by the locomotive inspector. This pooling of power brings bad results except when used in connection with a double inspection and separate reports.

Any defect reported on a locomotive by either engineman or inspector is promptly repaired in the roundhouse if possible; if not, the locomotive is sent to the shops.

SIGNALS.

337. **Signal rules.**—Employees whose duties may require them to give signals must provide themselves with the **proper appliances** and keep them in good order and ready for immediate use. **Flags** of the prescribed color must be used by day and **lamps** of the prescribed color by night.

Night signals will be displayed from **sunset to sunrise,** and whenever weather conditions might obscure day signals.

338. **Color signals.**

Color.	Indication.
(*a*) Red	Stop.
(*b*) Green	Proceed, and for other uses prescribed by the rules.
(*c*) Green and red	Proceed with caution, and for other uses prescribed by the rules.
(*d*) Green and white	Flag stop (see par. 361), and for other uses prescribed by the rules.
(*e*) Blue	Men working under or about cars on that track.

If the light system of a road taken over for military use **differs from above**, these rules must be changed to correspond to adopted system.

339. A **fusee** on or near the track **burning red** must not be passed until burned out.

340. **Hand, flag, and lamp signals.**

Manner of using.	Indication.
(*a*) Swung across the track	Stop.
(*b*) Raised and lowered vertically	Proceed.
(*c*) Swung vertically in a small circle across the track when the train is standing	Back.
(*d*) Swung vertically in a circle at arm's length across the track when the train is running	Train has parted.
(*e*) Swung horizontally back and forth above the head when the train is standing	Apply air brakes.
(*f*) Held at arm's length above the head when the train is standing	Release air brakes.

Any object waved violently by anyone on or near the track is a signal to stop, unless the engineer has reason to believe it to be a **ruse of the enemy** to induce him to stop the train, when he will proceed with caution.

Audible signals.

341. **Locomotive whistle signals** ("O" indicates short blast; "——" indicates long blast).

Sound.	Indication.
(*a*) O	Stop. Apply brakes.
(*b*) ——	Release brakes.
(*c*) —— O O O	Flagman go back and protect rear of train.
(*d*) — — — —	Flagman return from west or south.
(*e*) — — — — —	Flagman return from east or north.
(*f*) — — —	When running, train parted; to be repeated until answered by the signal prescribed by par. 340 (*d*). Answer to signal prescribed in par. 340 (*d*).
(*g*) O O	Answer to any signal not otherwise provided for.
(*h*) O O O	When train is standing, back. Answer to signal prescribed in pars. 340 (*c*) and 345 (*c*).
(*j*) O O O O	Call for signals.
(*k*) — O O	To call the attention of trains of the same or inferior class to signals displayed for a following section.
(*l*) —— —— O O	Approaching public crossings at grade.
(*m*)	Approaching stations, junctions, and railroad crossings at grade.

342. Should a train fail to answer signal (*k*), the train displaying the signals must **stop at once** and not proceed until they are acknowledged. On double track, signal (*k*) will only be used when passing trains.

343. A **succession of short sounds** of the whistle is an alarm for persons, or cattle, on the track, and calls the attention of trainmen to danger ahead.

344. The **explosion of one torpedo** is a signal to **stop**; the explosion of **two** not more than 200 ft. apart is a signal to **reduce speed**, and look out for a stop signal.

Torpedoes must not be placed near stations or road crossings where persons are liable to be injured by them.

345. **Air-whistle or bell-cord signals.**

Sound.	Indication.
(*a*) Two	When train is standing, start.
(*b*) Two	When train is running, stop at once.
(*c*) Three	When train is standing, back the train.
(*d*) Three	When train is running, stop at next station. To be answered as per par. 341 (*g*).
(*e*) Four	When train is standing, apply or release air brakes.
(*f*) Four	When train is running, reduce speed.
(*g*) Five	When train is standing, call in flagman.
(*h*) Five	When train is running, increase speed.
(*j*) Six	When train is running, increase steam heat.

Train signals.

346. The **headlight will be displayed** to the front of every train by night, but **must be concealed** when a train turns out to meet another and has stopped clear of main track, or is standing to meet trains at end of double track or at junction.

347. **Yard locomotives** will display the headlight to the front and rear by night. When not provided with a headlight at the rear, two white lights must be displayed, with a red light between them. Yard locomotives will not display markers.

348. **The following signals** will be displayed, one on each side of the rear of every train, as **markers**, to indicate the rear of the train: By day, a green flag; by night, a green light to the front and side and a red light to the rear, except when the train turns out to be passed by another; and **is clear of main track, when a** green light must be displayed to the side and rear.

349. **By night,** passenger and freight trains, while upon main track, will display a red light to the rear **in addition to the markers,** and freight trains, when practicable, will display a white light to the front from the top of caboose.

350. **All sections of a train,** except the last, will display two green flags, and in addition two green lights by night, in the places provided for that purpose on the front of the engine.

351. **Extra trains** will display two white flags, and in addition two white lights by night, in the places provided for that purpose on the front of the engine.

352. **When two or more locomotives** are coupled to the head of a train, the leading one only shall display the signals prescribed by pars. 350 and 351.

353. **When cars are pushed** by a locomotive (except when shifting or making up trains in yards), a white light must be displayed on the front of the leading car by night.

354. Each car on a passenger train must be connected with the locomotive by a **communicating signal appliance.**

355. A **blue flag** by day and a **blue light** by night displayed at one or both ends of a locomotive, car, or train, indicates that workmen are under or about it. When thus protected it must not be coupled to or moved. Workmen will display the blue

signals and the same workmen are alone authorized to remove them. Other cars must not be placed on the same track so as to intercept the view of the blue signals, without first notifying the workmen.

356. A **green and red flag** by day, and in addition a **green and red light** by night, placed beside the track, on the engineman's side, indicates that the track 3,000 ft. distant is in condition for speed of but **6 miles per hour**, and the speed of a train will be controlled accordingly.

357. A **green flag** by day, and in addition a **green light** by night, placed on the engineman's side at a point beyond the slow track, indicates that **full speed** may be resumed.

358. **Main-track switch targets** will show **green** when the switch is set for the main track, and **red** when set for sidings, crossings, or junction tracks. All other switch targets will show white or green.

359. A **slow board** placed alongside the track, reading "Reduce speed to ——— miles per hour," will indicate the rate of speed at which the track may be used at a point 3,000 ft. distant from such slow board. The rate of speed indicated on the slow board must not be exceeded. Beyond the point to be protected will be placed a sign reading "Resume full speed." A **green and red light** and a **green light**, respectively, will be suspended from these boards at night.

360. A signal **imperfectly displayed**, or the absence of a signal at a place where a signal is usually shown, must be regarded as a stop signal and the fact reported to the assistant superintendent.

361. The **combined green and white** signal is to be used to stop a train only at the flag stations indicated on the schedule of that train. When it is necessary to stop a train at a point that is not a flag station for that train, a red signal must be used.

TIME.

362. Trains will be operated on **standard time**, when standard time is available. Otherwise, a certain clock will be used, and its time used as a standard.

363. The clocks and watches used in the operation of the road must conform to the adopted time.

364. The time will be **sent over the road** at least once daily.

365. **All watches** of employees **will be examined** and certified to by some officer or watch inspector, who will certify to the condition and kind of watch carried by each employee.

TIME-TABLES.

366. Each time-table, from the moment it takes effect, supersedes the preceding time-table. A train of the preceding time-table shall retain its train orders and take the schedule of the train of the same number on the new time-table.

367. A train of the new time-table which has not the same number on the preceding time-table shall not run on any division (or district) until it is due to start from its initial station on that division (or district) after the new time-table takes effect.

368. The explanation in the time-table will state the direction that is **superior** on different parts of the line. Trains to the front will usually be superior to those going to the rear.

369. The trains of the time-table will be arranged in classes. Trains of the **first class** are superior to those of the second, trains of the **second class** to those of the third, and so on.

370. **Extra trains** are inferior to regular trains. All trains in the **superior direction**, as specified in the time-table, are superior to trains of the same class in the opposite direction.

371. **Regular trains** 12 hours behind their schedule lose both right and class, and can thereafter proceed only on train orders.

372. The time-table will give special instructions regarding the sidetrack to be taken, and any special rules that may be necessary to facilitate movement over the division for which the time-table is issued.

373. A list of **registering stations** will be indicated in the time-table, at which stations conductors of passenger and freight trains will register.

374. When one time is given in the time-table, unless otherwise specified, it is the leaving time. When two are given, they are the arriving and leaving times. **Schedule meeting or passing stations** have the time indicated in full-faced type. Where more than one train is to be met at a station, a small number between the time of leaving and arriving indicates the number of trains to be met.

375. The time-tables will indicate by reference marks the points where trains stop, meals are taken, and any other information necessary to clearly explain the time-table. They will also indicate the length of time that inferior trains will allow in **clearing the time** of superior trains at special points where pars. 381 and 382 do not apply for some local reason.

MOVEMENT OF TRAINS.

376. A train must not leave its initial station on any division (or district), or a junction, or pass from double to single track, until it has been ascertained whether all trains due, which are superior or of the same class, have arrived or left.

377. A train leaving its initial station on each division, when a train of the same class in the same direction is **overdue**, will proceed on its own schedule and the overdue train will follow at least **10 minutes later.**

378. **An inferior train** must keep out of the way of a superior train by the amount of time indicated in the time-table. A train failing to clear the main track in the time required in the time-table must **protect itself** by a flagman, who will go back a sufficient distance to insure protection. When recalled, he will return to his train, first complying with par. 426 when the conditions require it.

379. When a train **stops or is delayed on the main line,** similar precaution will be taken; and if danger exists from the front, a flagman will be sent out in that direction.

380. At **meeting points of trains** of the same class, the inferior train must clear the main track five minutes before the leaving time of the superior train. If necessary to back into siding, it will protect itself as hereinbefore provided.

381. **When extra trains meet,** the train of the superior direction will hold the main line unless otherwise directed. The train holding the main line will adjust the switch for the opposing train. At meeting points between trains of **different classes,** the inferior train must take the siding and clear the main line at least **5 minutes** ahead of the other's time.

382. **An inferior train** must keep at least **10 minutes** off the time of a superior train in the same direction.

383. **Trains must stop** at schedule meeting or passing stations if the train to be met or passed is of the same class, unless the switches are right and the track clear.

384. Trains should stop **clear of the switch** used by the train to be met, or passed, in going on the siding.

385. When the expected train of the same class is not found at the schedule meeting or passing station, the **superior train** must approach all sidings prepared to stop until the expected train is met or passed.

386. When trains meet by special order or time-table regulation, the conductors and enginemen will inform each other what train they are by word of mouth.

387. Unless some form of block signal is used, trains in the same direction must keep at least **10 minutes apart,** except in closing up at stations.

388. A train must not arrive at nor leave a station in **advance of its scheduled time.** At schedule passing stations between trains of the same class, the train to be passed, unless otherwise directed by special order, will remain at that point until the expected train has passed.

389. A train which **overtakes a superior train**, or train of the same class, so **disabled** that it can not proceed, will pass it if practicable, and if necessary will assume the schedule and take the train orders of the disabled train, proceed to the next open telegraph office, and there report to the assistant superintendent. The **disabled train** will assume the schedule and take the train orders of the last train with which it has exchanged, and will, when able, proceed to and report from the next open telegraph office.

390. A train must not display signals for a following section nor an extra train be run without orders from the chief dispatcher.

391. Trains must approach the end of the double track, junctions, railroad crossings at grade, and drawbridges prepared to stop, unless the switches and signals are right and the track is clear.

392. **All trains must stop** not less than 200 ft. nor more than 800 ft. before crossing any railroad at grade, except where **interlocking signals** are in use.

393. **Both engineman and fireman** must see signals at block stations, railroad crossings, drawbridges, and junctions, and communicate with each other the position of the signals.

394. When a train is to **back out of a siding**, the flagman must go a sufficient distance to the rear to insure full protection.

395. Before a train crosses over to or obstructs another main track, unless otherwise provided, it must be protected on that track.

396. **When a flagman goes back** to protect the rear of a train, the conductor can assign any one of the trainmen to perform his duties until he returns.

397. In case a **passenger train is due** within 10 minutes, or an approaching train is within sight or hearing, the flagman must remain out until it arrives.

398. **If a train should part** while in motion, trainmen must, if possible, prevent damage to the detached portions. The signals prescribed by pars. 340 (*d*) and 341 (*f*) must be given, and the front portion of the train kept in motion until the detached portion is stopped.

399. The **front portion** will then go back to recover the detached portion, running with caution and following a flagman. The **detached portion** must not be moved or passed until the front portion comes back.

400. **When cars are pushed** by a locomotive (except when shifting and making up trains in yards), a flagman must take a conspicuous position on the front of the leading car and signal the engineman in case of need.

401. When engines are cut off from trains at night and have to pass over highway crossings at grade or through station limits, a white light must be displayed on the rear of the tender.

402. **Messages or orders** respecting the movement of trains or the condition of track or bridges must be in writing and in train-order form.

403. Switches must be left set and locked for the main track after having been used.

404. Conductors are responsible for the position of the switches used by them and their trainmen, except where switch tenders are stationed.

405. A switch must not be left open for a following train, unless in charge of a trainman of such train.

406. **When a train backs** in on a siding to meet or be passed by another train, the engineman, when his locomotive is in the clear, must also see that the switch is properly set for the main track.

407. Enginemen must know that switches are properly set before they pull into or out of sidings or other tracks.

408. Trainmen or other employees **must not unlock** main-track switches, nor stand within 20 ft. of such switch on the approach of or during the passing of any train, and when practicable, on single track, he will stand on the **opposite side of the track** from the switch lever.

409. No attempt should be made to close the switch until the last wheels are off the switch rails. The person who locks the switch must grasp the chain and pull the lock to see that it is securely fastened, and, after having done so, must look at the switch rails and know that they are in their proper position.

410. Both switches to a crossover between main tracks must be locked for the main tracks during the passing of any train on the opposite track, and must not be unlocked or opened until the train is ready to use the crossover.

411. If any switch upon the main track is found to **to be defective,** or to have a **defective lock,** the switch must be secured and reported at once by telegraph to the assistant superintendent, by the conductor, engineman, or other person who may have discovered it.

412. Both conductor and engineman are responsible for the safety of their trains, and, under conditions not provided for by the rules, must take every precaution for their protection.

413. **In all cases of doubt or uncertainty, the safe course must be taken.**

414. Where **yard limits** are defined by limit boards, no locomotive or train is permitted to occupy main line in the time of regular trains without protection. At such points extra trains must approach at reduced speed, prepared to stop within their vision.

415. It must be understood that a train is **officially due to arrive** at a station upon its schedule departing time from the preceding station.

416. **When signals** displayed for a section **are taken down** at any point before that section arrives, the conductor will, if there be no other provision, notify the operator or agent in writing, who will immediately display the train-order signal and keep it in danger position for the benefit of opposing trains until the arrival of the train so flagged, and he must personally see that opposing trains are fully notified.

417. If the signals displayed for a section are taken down where there is no operator or agent, a flagman must be left for the purpose of notifying all opposing trains of the same or inferior class leaving such points that the section for which the signals were displayed has not arrived.

418. Conductors and enginemen taking down signals for a following section, as above, must not rely solely on notice being given at said station, but must themselves notify other trains met until they arrive and register at the next registering station.

419. **Work extras** will be assigned **working limits** by train order daily. In case orders should be given to a point outside of the working limits for water, fuel, or any other cause, the "working order" is thereby canceled, unless the subsequent order expressly states the contrary.

420. **Conductors of work extras** must know that all trains due have arrived before they start out with the work train. They must also leave a memorandum every evening, with the nearest telegraph operator, stating where the train will be at work during the following day, and this memorandum must be forwarded by telegraph to the chief dispatcher.

421. **Work extras** will be assigned working limits, and when operating upon **double track** must move, within these limits, with the current of traffic, unless train orders otherwise direct.

422. No freight train shall pass an open telegraph office not controlled by telegraph block system, except as provided by division time-tables, whether or not train-order signal be displayed, until the conductor and engineman have received orders from the train dispatcher, or a **release** or **clearance,** as the case may require, from the operator. Conductors and enginemen of passenger trains will observe the same rule at such telegraph offices as are regular stops for their trains. Extra freight trains will observe the same rule as regular freight trains, but extra passenger trains are not required to make stops solely for this purpose. They will be governed in this respect the same as regular passenger trains. This does not relieve operators from promptly displaying red signals whenever they have orders, or making other necessary efforts to stop trains.

423. A "**clearance**" (see par. 493) will be properly filled out and given, in duplicate, to the conductor and engineman of the train in all cases where the rules governing the movement of trains require conductors to ask for orders, provided the train-order signal is not displayed and no orders have been received for their train.

A clearance should be given in cases where trainmen are required to ask for orders and the train-order signal is not displayed, except as may be provided for by division time-tables.

424. If the train-order signal be displayed, but for another train, a **release** must be given instead of a clearance.

425. A "**release**" (see par. 491) will be properly filled out and given, in duplicate, to the conductor and engineman of a train when held by the train-order signal, in case no order has been received for their train, except as provided for by division time-tables.

426. **In case of stoppage between stations,** the flagman must immediately go back with not less than two torpedoes, and a red flag by day or a red and a white lantern and two red fusees by night, and at night place a lighted red fusee in the center of the track 500 ft. behind the rear of the train, proceeding by day or night to a point not less than ¾ mile distant from rear of train until he reaches a point where the danger signal can be seen not less than ¼ mile by the engineman of any approaching train. The **flagman will at once** place one torpedo on the rail on the engineman's side, and will remain at such point until the train has arrived, or until he is recalled. The engineman of approaching train, on seeing the flagman's signal, will immediately call for brakes, as evidence that the signal has been seen. When the flagman has been recalled, and no approaching train has arrived, he will place a second torpedo on the rail 200 ft. nearer his train than the first and return with all possible dispatch to his train. On exploding one torpedo, only, the approaching train will be brought to a full stop, and thereafter proceed with extreme caution, expecting to find some obstruction on the track. When a second torpedo is exploded, the engineman will know that the flagman has been recalled, and will proceed cautiously, keeping a sharp lookout for the train ahead. Immediately on the sound of the whistle recalling flagman, if there is not a clear view to the rear for ¼ mile from the rear of train, the train should be moved ahead at a speed of not less than 6 miles per hour until a point is reached where the track is straight for ¼ mile in the rear of train, always bearing in mind that the time of the flagman's return is the **period of greatest risk.** When the character of the road or weather makes it necessary, the flagman shall go a greater distance with the signals, so as to insure absolute safety. It must be distinctly understood that the conductor of the train, or the engineman of a locomotive running light, is held responsible for the safety of his train or locomotive. **When any train has been stopped** by a preceding train in the manner above mentioned, the conductor of the last train must use the same precautions with regard to any following trains as those heretofore described. When it is necessary to protect the front of a train, the same precaution shall be observed by the front brakeman or fireman. Conductors are held responsible for the proper protection of their trains under all circumstances.

427. A train must **not** be allowed to **stand on a curve** between stations, if practicable to avoid it.

428. **In addition to the above protection,** a red fusee will be considered an extra precaution, and will be used under circumstances requiring the same. Should a train, for any cause, be required to reduce its speed between stations, or at unusual points, a red fusee must be lighted and placed upon the track as an additional protection for the following trains, to insure a time limit between trains of not less than 5 minutes.

429. If a conductor or engineman discovers anything **wrong with the track,** bridges, or culverts which would be likely to cause an accident to a following train, he must leave a flagman, call the section men, and notify the train dispatcher by wire.

Conductors will report any switches found out of order or misplaced.

RULES FOR TRAIN MOVEMENT BY ORDERS.

430. If all trains run on a division were regular trains, and all such trains were always on time, trains could be run on the time-table without any assistance or intervention of the train dispatcher. This is manifestly impossible, and a system

of **telegraphic control** is used on all roads to control the movement of trains. Any train movement not covered by the time-table or by some rule of the road must be ordered by the train dispatcher. Each train leaves the terminal with orders to go to a certain point, where further orders will be received. The train proceeds to that point, unless sooner stopped by signal at some intervening point for different orders. Upon reaching the designated station, or if stopped (by signal) at some intermediate point, it receives orders that cover its move over another short section of line.

Whenever a regular train is late and can not run on its schedule, other trains are helped along by train orders which change the meeting or passing points of the respective trains for that particular trip.

431. Trains **meet** each other when moving in opposite directions, and they **pass** each other when moving in the same direction.

432. For movements not provided for by time-table, train orders will be issued by authority, and over the signature, of the chief train dispatcher. They must be **brief and clear,** in the **prescribed form** when applicable, and without erasure, alteration, or interlineation.

433. Each train order must be given in the **same words** to all persons or trains addressed.

434. Train orders will be numbered consecutively each day, beginning at midnight.

435. Train orders must be addressed to those who are to execute them, naming the place at which each is to receive his copy. Those for a train must be addressed to the conductor and engineman, and also to anyone who acts as pilot. A copy for each person addressed must be supplied by the operator.

436. Each train order must be written in full in a book provided for the purpose at the office of the chief train dispatcher, and with it recorded the names of those who have signed for the order, the time and the signals which show when and from what offices the order was repeated and the responses transmitted, and the train dispatcher's initials. These records must be made at once, and never from memory or memoranda.

437. Regular trains will be designated in train orders by their train numbers (written in words *and* figures), engine numbers, and conductors' names, as "*2d No. Ten 10 Eng. 504, Smith;*" extra trains, by engine numbers and conductors' names, as "*Extra 798, White,*" with the direction as *North, South, East,* or *West.* **Time in body of the orders** must be written in words and duplicated in figures. Figures must not be surrounded by brackets, circles, or other characters, but appear plainly without accompanying marks.

438. **To transmit a train order,** the signal "31" or "19" must be given to each office addressed, the number of copies being stated, thus: "31 copy 5;" "19 copy 2." A "31" order is not completed until after signed by conductor and operator. A "19" order is completed on signature of operator.

439. A train order to be sent to two or more offices must be **transmitted simultaneously** to as many of them as practicable. The several addresses must be in the order of superiority of trains, each office taking its proper address. When not sent simultaneously to all, the order must be sent first to the superior train.

440. When a meeting point is to be made between two trains at a certain station, the order, when practicable, should be sent for said trains to stations at either side of the actual meeting point; also to the operator at the actual meeting point, if a telegraph office.

441. The numeral abbreviation "12" will be used at the end of a train order immediately preceding the signature. **"12" signifies:** "Do you acknowledge receipt of this order, and do you fully understand it?"

442. In responding to train orders, conductors or others will use the abbreviation **"13," which signifies:** "I hereby acknowledge the receipt of order, and state that I fully understand and will execute the same."

443. Operators receiving train orders must write them in manifold during transmission, and if they can not at one writing make the requisite number of copies, **must trace others** from one of the copies first made.

Operators required to make new or additional copies of an order will, in every instance, repeat these copies the same as the original order.

444. When a train order has been transmitted, operators must **first set their signals,** then give "X" response (see par. 333), and (unless otherwise directed) repeat it at once from the manifold copy in the succession in which the several offices have been addressed, and then write the time of repetition on the order.

445. Each operator receiving the order should observe whether the others repeat correctly.

446. Those to whom the **"31" order** is addressed, except enginemen, **must read it aloud,** then sign it, and the operator will send their signatures preceded by the number of the order to the train dispatcher. The response "O. K." and the time, with his initials, will then be given by the train dispatcher. Each operator receiving this response will then write on each copy "O. K.," the time, train dispatcher's initials, and his own last name in full, and then deliver a copy to each person addressed, except enginemen. The copy for each engineman must be delivered to him personally by the conductor, and the engineman must read it aloud to the conductor before proceeding.

447. When a **"19" order** is received at actual meeting point as per last clause of par. 440 the operator will set his signal, give "X" response, repeat the order, sign his name, and receive "O. K." to same, and after receiving the signature of the conductor will deliver two copies of the order to the conductor of the train first arriving. This rule applies to time and positive meet orders. On a single-track road, a **"19" order** is used only to **confer a right** upon a train, and **not to restrict the rights** or the superiority of a train.

448. Conductors must **show their orders** to rear brakeman or flagman, and the engineman to the fireman, and (in case of a freight train) to the head brakeman, who are required to read them.

449. A **train order must be acknowledged** by the operator responding: "X; (*number of train order*) to (*train number*)," with the operator's initials and office signal. The operator must then write on the order his initials and the time.

450. **"O.K." must not be given** to a train order for delivery to an inferior train until the "X" response has been sent by the operator who receives the order for the superior train.

451. When the "X" response is given to a train order and before the "O. K." has been received, an order must be treated as a **holding order** for the train addressed, and must not be delivered until it has been repeated and the "O. K." has been given.

452. If the **line fails** before an office has sent the "X" response, the order at that office is of no effect and must be there treated as if it had not been sent.

453. The operator who receives and delivers a train order must preserve the **lowest copy.**

454. For train orders delivered by the train dispatcher, the requirements as to the record and delivery are the same as at other points.

Such orders shall be first written in manifold so as to leave an impression in the record book, from which transmission shall be made.

455. A **train order** to be delivered to a train at a **point not a telegraph station,** or at one at which the telegraph office is closed, must be addressed to:

"*C & E.* ------ *at* ------, *care of* ------," and forwarded and delivered by the conductor or other person in whose care it is addressed. In such cases the "O. K." will be given upon the signature of the person by whom the order is to be delivered, who must be supplied with copies for the conductor and engineman addressed, and a copy upon which he shall take their signatures. This copy he must deliver to the first operator accessible, who must preserve it and at once transmit the signatures of the conductor and engineman to the train dispatcher.

Orders so delivered must be acted on as if "O. K." had been given in the usual way.

For orders which are sent in the manner herein provided, to a train, the superiority of which is thereby restricted, "O. K." must not be given to an inferior train until the signature of the conductor and engineman of the superior train has been received by the train dispatcher.

456. When a train is named in a train order, **all its sections** are included unless particular sections are specified, and each section included must have copies addressed and delivered to it.

457. An operator **must not give the "X"** response to a train order for a train the locomotive of which has passed his train-order signal, until he has ascertained that the conductor and engineman have been notified that he has orders for them.

458. **Train orders once in effect** continue so until fulfilled, superseded, or annulled. Any part of an order specifying a particular movement may be either superseded or annulled.

459. When a conductor or engineman relieves another before completion of a trip, they exchange orders, and before proceeding conductor must compare orders with the new engineman.

460. A train must not leave a terminal without a clearance, release, or train order.

461. A fixed signal must be used at each train-order office, which shall indicate "stop" when trains are to be stopped for train orders. When there are no orders the signal must indicate "proceed," except when used to keep trains a required distance apart.

462. When an operator **receives an order** for a train, before acknowledging by the "X" response to the train dispatcher the receipt of same he will display his train-order signal at "stop" position; and until the orders have been delivered or annulled, the signal must not be restored to "proceed."

While "stop" is indicated, trains must not proceed without a release (par. 491).

463. Operators must have the proper appliances for hand signaling ready for immediate use if the fixed signal should fail to work properly.

464. If a signal is not displayed at a night office, even a train which has not been notified must stop and ascertain the cause, and report the facts to the train dispatcher from the next open telegraph office.

465. When a semaphore is used, the arm indicates **"stop" when horizontal**, and **"proceed" when in an inclined position.**

466. Operators will promptly record and report to the train dispatcher the time of departure of all trains and the direction of extra trains. They will record the time of arrival of trains and report it when so directed.

FORMS OF TRAIN ORDERS.

467. **Form A.—Fixing meeting points for opposing trains:**

(1) _____ will meet _____ at _____
(2) _____ will meet _____ at _____, _____ at _____ (and so on).

Examples.

(1) *No. Three 3 Eng. 96, Jones, will meet Second No. Four 4 Eng. 105, Lane, at Siam.*

(1) *No. Five 5 Eng. 176, White, will meet Extra 95 West, Phillips, at Hongkong.*

(1) *Extra 652 North, Williams, will meet Extra 231 South, Yates, at Yokohama.*

(2) *No. One 1 Eng. 80, King, will meet No. Two 2 Eng. 100, Vilas, at Bombay, Second No. Four 4 Eng. 65, Peal, at Siam, and Extra 95 West, Phillips, at Hongkong.*

Trains receiving these orders will run with respect to each other to the designated points, and there meet, in the manner provided by the rules.

468. **Form B.—Directing a train to pass or run ahead of another train:**

(1) _____ will pass _____ at _____
(2) _____ will run ahead of _____ _____ to _____
(3) _____ will pass _____ at _____ and run ahead of _____ _____ to _____.

Examples.

(1) *No. One 1 Eng. 67, Palmer, will pass No. Three 3 Eng. 105, Seton, at Khartoum.*

(2) *Extra 594, East, Potter, will run ahead of No. Six 6 Eng. 1015, King, Bengal to Madras.*

(3) *No. One 1 Eng. 67, Palmer, will pass No. Three 3 Eng. 105, Seton, at Khartoum and run ahead of No. Seven 7 Eng. 415, Asker, Madras to Bengal*

When under (1) a train is to pass another, both trains will run according to rule to the designated point and there arrange for the **rear train to pass promptly**.

Under (2) the second-named train must not exceed the speed of the first-named train between the points designated.

469. **Form C.—Giving a train the right over an opposing train:**

(1) _____ has right over _____ _____ _____ to _____.

Examples.

(1) *No. One 1 Eng. 67, Palmer, has right over No. Two 2 Eng. 85, Bates, Mecca to Mirbat.*

(2) *Extra 37 South, Engle, has right over No. Three 3 Eng. 105, Seton, Natal to Ratlam.*

This order gives the train first named the right over the other train between the points named.

If the trains meet at either of the designated points, the **first-named train** must take the siding, unless the order otherwise prescribes.

470. Under (1), if the second-named train reaches the point last named before the other arrives, it may proceed, keeping clear of the opposing train as many minutes as such train was before required to clear it under the rules.

If the second-named train, before meeting, reaches a point within or beyond the limits named in the order, the conductor must stop the other train where it is met and inform it of his arrival.

471. Under (2), the regular train must not go beyond the point last named until the extra train has arrived.

When the extra has reached the point last named, the order is fulfilled.

472. The following modification of this form of order will be applicable for giving a work extra the right over all trains in case of emergency:

(3) Work extra _____ has right over all trains between _____ and _____ from _____ m. to _____ m.

Example.

Work extra 275, Smith, has right over all trains between Manila and Honolulu from Seven 7 p. m. to Twelve 12 midnight.

This gives the work extra the exclusive right between the points designated between the times named.

473. **Form D.—Giving regular trains the right over a given train:**

(1) Regular trains have right over _____ between _____ and _____.

Example.

Regular trains have right over No. One 1 Eng. 67, Palmer, between Moscow and Berlin.

This order gives to regular trains receiving it the right over the train named in the order, and the latter must clear the schedule times of all regular trains as if it were an extra.

474. **Form E.—Time orders:**

(1) _____ will run _____ late _____ to _____.

(2) _____ will run _____ late _____ to _____ and _____ late _____ to _____, etc.

(3) _____ will wait at _____ until _____, for _____.

Examples.

(1) *No. One 1 Eng. 67, Palmer, will run twenty 20 mins. late, Joppa to Mainz.*

(2) *No. One 1 Eng. 67, Palmer, will run twenty 20 mins. late, Joppa to Mainz, and fifteen 15 mins. late, Mainz to Muscat, etc.*

(3) *No. One 1 Eng. 67, Palmer, will wait at Muscat until Ten 10 a. m. for No. Two 2 Eng. 89, Willits.*

475. (1) and (2) make the schedule time of the train named, between the points mentioned, as much later as stated in the order, and any other train receiving the order is required to run with respect to this later time as before required to run with respect to the regular schedule time. The time in order should be such as can be easily added to the schedule time.

476. Under (3), the train first named must not pass the designated point before the time given unless the other train has arrived. The train last named is required to run with respect to the time specified, as before required to run with respect to the regular schedule time of the train first named.

477. **Form F.—For sections:**

(1) _____ will display signals _____ to _____ for _____.

Examples.

Eng. 20, Smith, will display signals and run as First No. One 1 London to Paris.

No. One 1 Eng. 67, Palmer, will display signals London to Dover for Eng. 85, King.

Second No. One 1 Eng. 105, King, will display signals London to Dover for Eng. 90, Roberts.

478. This form may be modified as follows:

Engs. 70, Creighton, 85, King, and 90, Knox, will run London to Dover as First, Second, and Third No. One 1 respectively.

Under these examples, the engine last named will not display signals.

479. **For annulling a section:**

Eng. 85, Kingdon, is annulled as Second No. One 1 from Chatham.

If there are other sections following, add:

Following sections will change numbers accordingly.

Each section affected by the order must have copies and must arrange signals accordingly.

480. **Form G.—Extra trains:**

(1) Eng. _____ will run extra _____ to _____.

(2) Eng. _____ will run extra _____ to _____ and return to _____.

Examples.

(1) *Eng. 99, Jones, will run extra Berber to Gaza.*

(2) *Eng. 99, Jones, will run extra Berber to Gaza and return to Cabul.*

A train receiving this order is not required to protect itself against opposing extras unless directed by order to do so, but must keep clear of all regular trains as required by rule.

(3) Eng. _____ will run extra leaving _____ on _____, as follows, with right over all trains:

Leave _____.
Leave _____.
Arrive _____.

Example.

(3) *Eng. 77, Wilson, will run extra leaving Turin on Thursday, February 17, as follows, with right over all trains:*

Leave Turin Eleven thirty 11.30 p. m.
Leave Pekin Twelve twenty-five 12.25 a. m.
Leave Canton, One forty-seven 1.47 a. m.
Arrive Rome Two twenty-two 2.22 a. m.

This order may be varied by specifying the kind of extra and the particular trains over which the extra shall not have the right. Trains over which the extra

is given the right must clear the time of the extra 10 minutes. The train dispatcher may increase the clearance time at his discretion.

481. **Form H.—Work extra:**

(1) Work extra _____ will work _____ until _____ between _____ and _____.

Examples.

(1) *Work Extra 292, Smith, will work Seven 7 a. m. until Six 6 p. m. between Berne and Turin.*

482. The working limits should be as short as practicable, to be changed as the progress of the work may require. The above may be combined thus:

(a) *Work Extra 292, Smith, will run Berne to Turin and work Seven 7 a. m. until Six 6 p. m. between Turin and Rome.*

When an order has been issued to "work" between designated points, no other extra shall be authorized to run over that part of the track without a definite meeting order with the work extra.

When it is anticipated that a work extra may be where it can not be reached for orders, it will be directed to report for orders at a given time and place, and a meeting order issued with other extra.

483. To enable a work extra to work upon the time of a regular train, the following form may be used:

(b) *No. Fifty-five 55 Eng. 342, Jones, will wait at Berne until Six 6 p. m., for Work Extra 292, King.*

A work extra receiving this order will work upon the time of the train mentioned in the order as per par. 381.

A train receiving this order must not pass the designated point before the time given unless the work extra has arrived.

484. **Form J.—Holding order:**

(1) Hold _____ at _____.

Examples.

(1) *Hold No. Two 2 Eng. 481, Palmer, at Berlin.*
(2) *Hold all eastbound trains at Berlin.*

This order will be addressed to the operator, and acknowledged in the usual manner. It must be respected by conductors and enginemen of trains thereby directed to be held as if addressed to them.

485. When a train has been so held, it must not proceed until the order to hold is annulled, or an order given to the operator in the form:

"_____ *may go.*"

Form J will only be used when necessary to hold trains until orders can be given, or in case of emergency.

486. **Form K.—Annulling a regular train:**

(1) _____ of _____ is annulled _____ to _____.
(2) _____ due to leave _____ _____, is annulled _____ to _____.

Examples.

(1) *No One 1 Eng. 392, Smith, of Feb. 29, is annulled Alaska to Halifax.*
(2) *No. Three 3 Eng. 768, Wilson, due to leave Naples Saturday, Feb. 29, is annulled Alaska to Halifax.*

The train annulled loses both right and class between the points named, and must not be restored under its original number between those points.

487. **Form L.—Annulling an order:**

(1) Order No. _____ is annulled.
(2) Order No. _____ to _____ at _____ is annulled.

If an order which is to be annulled has not been delivered to a train, the annulling order will be addressed to the operator, who will destroy all copies of the order annulled but his own, and write on that:

Annulled by Order No. _____.

Examples.

(1) *Order No. Ten 10 is annulled.*
(2) *Order No. Ten 10 to C. & E. No. Two 2, at Alaska, is annulled.*

An order that has been annulled must not be reissued under its original number.

488. In the address of an order annulling another order, the train first named must be that to which right was given by the order annulled, and when the order is not transmitted simultaneously to all concerned, it must be **first sent** to the point at which that train is to receive it, and the required response received, before the order is sent for other trains.

489. **Form M.—Annulling part of an order:**

(1) That part of Order No. _____ reading _____ is annulled.

Example.

That part of Order No. Ten 10 reading No. One 1 Eng. 67, Palmer, will meet No Two 2 Eng. 58, King, at Sparta is annulled.

In the address of an order annulling a part of an order, the train first named must be that to which right was given by the part annulled, and when the order is not transmitted simultaneously to all concerned, it must be first sent to the point at which that train is to receive it, and the required response received before the order is sent for other trains.

490. **Form P.—Superseding an order or a part of an order:** This order will be given by adding to prescribed forms the words "instead of _____."

(1) _____ will meet _____ at _____ instead of _____.
(2) _____ has right over _____ _____ to _____ instead of _____.
(3) _____ will display signals for _____ _____ to _____ instead of _____.

Examples.

(1) *No. One 1 Eng. 765, King, will meet No. Two 2 Eng. 642, Palmer, at Hongkong instead of Bombay.*

(2) *No. One 1 Eng. 765, King, has right over No. Two 2 Eng. 642, Palmer, Mecca to Medina instead of Mirbat.*

(3) *No. One 1 Eng. 765, King, will display signals for Eng. 85, Smith, Astrakhan to Teheran instead of Cabul.*

An order that has been superseded must not be reissued under its original number.

In the address of a superseding order, the train first named must be that to which right was given by the order superseded, and when the order is not transmitted simultaneously to all concerned, it must be **first sent** to the point at which that train is to receive it and the required response received before the order is sent for other trains.

491. **Release:**

(*a*) From Train Order Signal, but not from Block, unless stamped "BLOCK IS CLEAR:"

_____, 19

C. & E., No. _____.
My train-order signal is displayed for _____
I have no orders for _____
Last train ahead left at _____
_____, Signalman.

Or, as per par. 617, signalmen will fill out the following release:

(*b*) From train order *and* block signal:

Signal is displayed for _____ and _____ to meet or pass at _____. Except as above block is clear.
Issued at _____ m.
Last train ahead left at _____ m.
_____, Signalman.

NOTE.—When a block signal is at diagonal it only indicates that block is clear to the first switch reached at the next block station.

Should any train have orders not to pass a station *without orders*, the receipt of this blank does not release it, but in such cases regular train orders must be obtained.

492. **Caution card:**

To C. & E., Train _____
Block is not clear. You may proceed with caution, prepared to stop within your vision.

_____, Signalman.

493. **Clearance:**

_____, 19

C. & E., No. _____
No orders have been received at _____ station for train No. _____, due at said station at _____ m., _____19
Last train ahead left at _____m.

_____, Operator.

NOTE.—Should any train have orders not to pass any station *without orders*, the reception of this blank does not release it, but in such cases regular orders must be obtained.

494. **Standard train-order blank for "31" order:**

Form 31. Form 31.

UNITED STATES MILITARY RAILWAY.

TRAIN ORDER No. *10.*

March 27, 1906.

To *C. & E., No. 2.* At *Joppa.*
To _____

X *J. D. B.* Opr. *1.45 a.* m.

Train ahead left at *12.30 a.* m.

No. One 1 Eng. 765, King, has right over No. Two 2 Eng. 642, Palmer, Mecca to Medina instead of Mirbat.

"12" P. G. C.

Conductor and engineman must both have a copy of this order.

Repeated at *2.20 a.* m.

CONDUCTOR.	TRAIN.	MADE.	TIME.	OPR.
Palmer	*2*	*Complete*	*2.20 a.* m	*Black*

495. **Standard train-order blank for "19" order:**

Form 19. Form 19.

UNITED STATES MILITARY RAILWAY.

TRAIN ORDER No. *10.*

March 27, 1906.

To *C. & E., No 1.* At *Teheran.*

X ....., Opr. *1.45 a.* m.

No. One 1 Eng. 765, King, will meet No. Two 2 Eng. 85, Smith, at Astrakhan instead of Cabul.

"*12*" *P. G. C.*

Conductor and engineman must both have a copy of this order.

Made *complete* time *1.50 a.* m. *Black*, Opr.

496. **Trains.—First-class** trains are usually regular passenger trains. **Second-class** trains are usually time freights, and **third-class** trains are usually dead freights, empties, and local freights. The number of regular passenger trains to be run daily will be specially determined in each case, and will not provide for larger troop movements than parts of companies. Where one company or more is to be moved, extra cars will be added to the regular passenger train, or extra trains will be run. These extra trains can, by train orders of the train dispatcher or his superior, be given any rights on the road that are necessary.

497. **Time freight** is freight that must be delivered within a certain time, and must be forwarded without delay.

498. **Dead freight** is freight that need not be hurried and that delay can not harm. Military conditions will sometimes change the classification from dead freight to time freight. A hurried shipment of ammunition illustrates the case in point.

499. **Local freight** is freight shipped from one point on a division to another point on the same division, or to a point on an adjacent division. On a military road, the number of regular time freights, or other freights, will depend entirely upon the local conditions. On any division at least one local freight will be run each way daily. These locals delivery freight from the division terminals to various points along the division, distribute empties where they may be required, and pick up loads at the intermediate stations and carry such loads to the other division terminal, where they are either placed in through trains for their ultimate destination or are forwarded on another local if their destination is on the next division.

Time freights may stop at intermediate stations to pick up an important car, or such a car may be forwarded by a local freight train to the nearest large station, or division terminal, before it is placed in a through freight train.

500. When a shipment of through freight **requiring an extra train** is received on a division, the train dispatcher of that division promptly notifies the **train dispatcher of the next division** of the number of cars of such shipment, together with the class and probable time of arriving on the next division. This permits the next train dispatcher to arrange his power and train crews to take care of such extra shipment.

501. The **ordinary accumulation** of cars that collect at division terminals are arranged into the **regular** trains by the yardmaster, who notifies the roundhouse foreman of the locomotive needed, and the train crew to run the train. When the total accumulation of cars can not be run in the regular trains, he notifies the chief dispatcher, who orders out **extras** enough to move the cars. As soon as a train is made up and ready to move, the conductor of the train makes up a **consist,** or **detail sheet,** showing the composition of his train. This sheet shows the date, train number, time of leaving, number of locomotive, names of engineer and conductor, and gives the contents and destination of each load, and will state when carded, or specify time freight. For **time freight,** they will give the junction point through which it is routed. **For empties** in their train, they give the initials, destination, size and kind of each car. This consist is telegraphed to the chief dispatcher, who thus knows the contents of each train. He has at hand the local car sheet, described in par. 270, and thus can arrange to **keep the train full,** distributing empties where needed and picking up loads at intermediate stations on the line, and he issues telegraphic orders to accomplish this result. In case the train is late, the consist enables him to order certain cars of unimportant freight set out to lighten the train and thus increase the speed.

502. If all the cars in the train are loaded to their full capacity the weights will be given in the consist; otherwise, the chief dispatcher estimates the weight of the train from a list that he keeps showing the approximate weight of the different kinds of empties and of the same cars normally loaded, and from which he can form a correct estimate of the tonnage in each train. The chief dispatcher must endeavor to keep each locomotive loaded to its **tonnage rating** over each section of the division. Standing instructions should be issued that when trains are not filled to the tonnage rating of the engine this opportunity will be taken to deliver coal along the line.

503. Agents will report daily the amount of **coal on hand,** so as to give timely notice for a new shipment.

TIME-TABLES.

504. After the military controlling staff has decided on the number of trains that must be run for military purposes, the places at which such trains must stop to fulfill requirements, and the amount of civil traffic that will be permitted, they turn this data over to the railway officials to work up into a time-table.

The conditions laid down have determined the number of regular trains of the various classes that must be run, and the time of starting from the initial station will be fixed so as best to meet the military requirements.

The speed of the trains will depend upon the condition of the roadbed, the maximum grade, power of the engine, loads to be hauled, etc., as laid down in pars. 206, 207.

505. A time-table is first made out in **graphic form** (see fig. 128). A rectangle is laid out, and is divided by perpendicular parallel lines into equal divisions representing the 24 hours of the day, subdivided into 5-minute intervals. It is divided by horizontal parallel lines whose distances apart represent the distances between corresponding stations for the scale assumed. This drawing is then fastened to a large drawing board.

Having determined the speed for each class of train, the movement of the train can be indicated on the graphic table by a right line, if the speed between stops is assumed to be uniform. At stations where there is a stop of over 2 minutes, the train movement will be indicated by a horizontal line at that station. Fig. 128 is a type of time-table for a single-track road. On a single-track road all trains meet and pass at stations, therefore all lines representing train movements must intersect on the horizontal lines indicating stations.

Having determined on the speed for the various trains, the trains will be arranged so as to least interfere with one another. Slow trains must take the sidetrack for fast trains; and if a slow train starts just ahead of two or three superior trains, it may be laid out on sidings for 2 or 3 hours while waiting for such fast trains to pass it. It is wise, therefore, to group the trains, and to start the slow trains immediately after the group of fast trains has left the terminal. By this means it is often possible to get the fleet of slow trains across a division with only one or two delays on account of stops for superior trains.

The train movements (fig. 128) are represented by threads, and, for the sake of clearness on the board, threads of different colors represent different classes of trains.

Each thread is tagged at the upper and lower end, and by this means it is easy to follow every train across the board.

Where speed changes, or a train stops, the change in direction of the thread is made by driving a pin into the board at such points of change.

When a new train is put on, having the time of departure and the speed of the train, it is easy to thread this train onto the time-table board, making such corrections in the other threads as may be necessary.

On a **double-track road** the manner of making a time-table is similar to that just described, but is simpler, since all trains go in one direction on each track, and there is no need of working out meeting points for trains from opposite directions.

506. Having completed the graphic time-table, the **working time-table** is made up by taking the times from the board and inserting them in their proper places in the printed time-table. Such time-tables will show the distances between stations, the capacity of passing tracks in each direction, the stations at which all trains stop, watering stations, coaling stations, etc. Any **special rules** that change the time that one train must clear the time of another will be published therein, as will also a list of registering stations, railway grade crossings, junction points, and overhead obstructions. A list of railway officers, officials, and surgeons, with their addresses, will be printed on the time-table.

507. The time-table will show the **tonnage rating** of locomotives of different classes over different sections of the division, for fast freights and for slow freights, together with empty weights of the various kinds of cars used.

FREIGHT.

508. All supplies must be shipped on **shipping bills** or receipts for freight received. One copy is sent by mail to the consignee and one copy is held by the station agent where the freight was received. In loading supplies, endeavor should be made to load each car to its full capacity, if this can be done and not mix shipments to too great an extent. Hay and hard-tack are examples of supplies that utilize only about two-thirds of the actual capacity of a flat car or gondola, whereas if loaded into a box car, they utilize about 90% of the actual capacity. Other supplies, such as grain, flour, sugar, etc., must be loaded in box cars, and easily load the car to its full capacity without occupying all the space. For **important shipments** a copy of the receipt may be sent to the agent at the destination so that he may be ready to care for the shipment on its arrival.

509. All freight to be shipped on a military railway will be delivered to the agent in exchange for a receipt for goods shipped. This receipt will be of the simplest form, indicating the date of shipment, name of consignor and consignee, and address of each, the serial number of the receipt, a list of the packages, with weight, marks, and contents of each. The agent or clerk will keep a duplicate of the receipt and will ship the freight on a waybill. The original receipt is delivered to the consignor to be sent to the consignee (pars. 508 and 511).

510. The **waybill** will be given the conductor of the train carrying the goods, and will indicate the routing desired in addition to the information contained in the receipt.

511. The conductor who first receives the waybill turns it over to the yardmaster at the end of his run. The latter delivers the waybill to the conductor who next takes the car. This is continued to the destination of the car, and the waybill and freight are there delivered to the receiving agent, who takes a list of the door seals, checks the freight against the waybill, and delivers the freight to the consignee, taking up the original receipt for goods shipped, or taking an **informal receipt** if the original has not been received by the consignee and the latter is known by the agent to be responsible.

512. **Time freight** will be shipped on a **red waybill**, and must always be hurried through. Ordinary freight will be shipped on a waybill printed in **black**; and railway property on a waybill printed in **blue**. These three classes will cover all usual shipments, and the difference in color makes oversights and delays less frequent.

513. **Stock.**—In moving live stock over a railroad it has been found satisfactory to move the stock for a distance that can be covered in about 10 hours, and at this point unload the stock and detain them for 10 hours for feed and water, and then

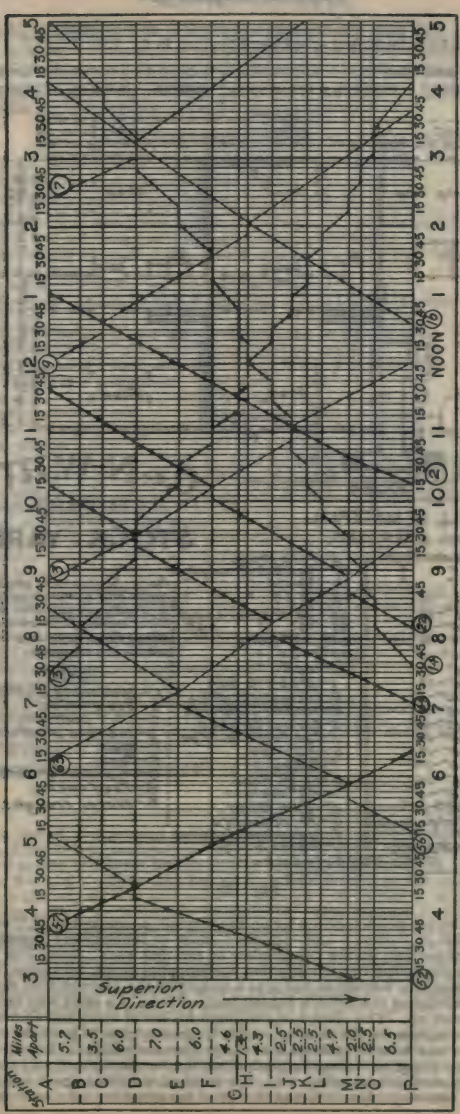
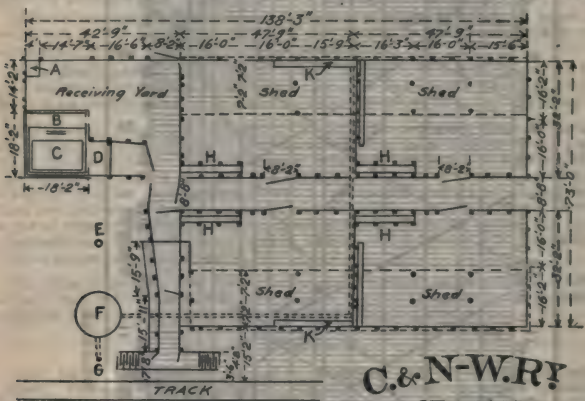


FIG. 128.—PART OF GRAPHIC TIMETABLE.

forward them. This plan will necessitate stockyards at such stations. A plan and bill of material for a **four-pen stockyard** is given in fig. 129.

514. **Overs and shorts.**—If any packages indicated on the waybill are not found when the shipment is received, a list of such "**shorts**" is taken. If there are any



C.&N-W.RY.
STANDARD
STOCK YARD

BILL OF MATERIAL
FOR 4 PEN YARD

8-8' Cedar Posts	2-Gate Props
138-12' " "	12-3/4 X 12 Bolts, sq. h.n.
46-16' " "	2-3/4 X 16 " " "
2-1"X3"-16'	48-1/2 X 5 " "
244-1"X6"-16'	28-7/8" Washers, cast
300-1"X10"-16'	96-5/8" " wgt.
64-2"X4"-16'	120#-10d Nails
14-2"X6"-10'	250#-40d "
2-2"X6"-14'	75#-60d "
28-2"X6"-16'	1-2"X6"-16' Oak
298-2"X10"-16'	2-Hinges (see dt'l.)
19-3"X10"-16'	2-Hinged Supports
4-3"X10"-18'	3-Corner Braces
2-4"X8"-14'	1-Eye Bolt 4" lg. 1" Eye
2-4"X8"-16'	6-Ft. 2" Pipe
1-6"X6"-14'	1-Pulley
1-6"X6"-16'	15-Ft 3/4" Rope
1-6"X8"-8'	1-80# Weight
2-6"X8"-16'	5-1/2"X4" Bolts
9-8' Gates, compl.	5-5/8" Washers
3-4'-8' " "	1-Apron (end of chute)
10-3/4"X18" Bolts,	1-Water Trough

17-No. 8709 Gate Locks

Note: Scale house, sheds, feed racks and water supply to be located as conditions warrant. Bill of material for chutes, pens, sheds, feed racks and inclined platform complete.

INDEX

A—Unloading platform.
B—Scale house.
C— " platform.
D—Inclined platform.
E—Well.
F—Tank.
G—Hydrant for water in cars
H—Feed racks.
K—Water troughs.

FIG. 129.

packages in the car not accounted for on the waybill, a similar list of "**overs**" is made. This list of "overs" and "shorts" must be immediately reported to the division superintendent, giving the number of car that such "overs" or "shorts" occurred in, a list of the transfer stations, the shipping point, consignee, and such other notes from the waybill as will give a history of the journey that the car has made. In the office of the division superintendent there is a clerk who immediately takes the matter up. This clerk looks through his list of overs and shorts received from all other agents on the division, and is frequently able to locate lost packages from such list and to send extra ones to the proper destinations. For all packages that can not be found, or whose destination can not be determined, an investigation is immediately started, beginning with the original shipping agent and following through the various persons who had charge of the shipment en route and at the

same time a division list of "overs" and "shorts" is sent to the general superintendent, in whose office a similar investigation is made from the combined reports of "overs" and "shorts" received from the various division superintendents.

515. In investigating for overs and shorts it will be found advantageous to make out a printed list of numbered questions, such as follows:

SUPERINTENDENT'S OFFICE, _____ DIVISION,

_____, 19

Agent, Condr._____, File _____

Please see papers attached and comply with request No. _____

1. Examine your warehouse, platform, billing, etc., and advise if loaded as billed.
2. If you find not loaded as billed, give full explanation.
3. Was freight checked when loaded and by whom? How long after loaded before car was sealed?
4. For what stations did you load similar freight?
5. Into what car might this freight have been loaded in error and for what points?
6. Who had car _____ out of your station, and on what date?
7. Are you still short the within-mentioned packages?
8. Car _____ into your station _____. Were you over, and was car made empty? If not, give disposition.
9. Car _____ delivered to your division at _____, date _____ Please trace to an empty and advise if over.
10. Trace through to destination and advise if freight has been received and from what source.
11. Has shortage been filled? If so, give waybill reference on which received?
12. Give your transfer record, disposition of original car if not empty. Did you transfer similar freight, and for what points? How do you account for this shortage?
13. See short report attached. Are you over?
14. You had car _____ in train _____ date _____ Where did you leave it? Are you positive freight was not in car? Can you account for shortage? Did you unload similar freight? If so, at what stations? Give all around seals when taken and when left and say at what stations opened.
15. See over report attached. Are you short, and on what billing?
16. Give record of car passing. Show train, date, conductor, seal record, and advise if you check over.
17. See over report attached. Did you handle similar freight on your train this date? Can you give disposition?
18. Who had car _____ to you and under what seals?
19. Please show delivery to the _____ division.
20. See over report. Can you furnish billing to cover?
21. See attached over report. Will this fill your shortage?
22. First agent note and forward consecutively as shown above, last-named agent forwarding papers to this office.

Please return papers promptly to this office.

Yours truly,

_____, Division Superintendent.

Make a list of the persons to be questioned, and opposite each name set the numbers of the above questions that it is desired to have each answer. Send this list to first person and direct him to answer his questions and then forward all the papers to No. 2, etc. Thus this list of questions is sent to the original shipping agent with the request that he answer questions 1 to 6, inclusive, and then forward papers to first conductor to answer question 14. This conductor answers his question and forwards the papers to second conductor, etc. If nothing develops from the investigation of conductors, the papers may then be sent back to the receiving freight agent with request that he answer question 7, or to any agent who opened the car en route, for answer to question 8. The various questions suggest the persons to whom the paper should be sent in the investigation. A prompt investigation of all overs and shorts is especially necessary on a military railway.

516. **In loading freight**, the agent will always check all articles received before giving the waybill; and when such freight is loaded into the cars, some system must be adopted which will make sure that the freight is placed in the proper car and that all the freight on the bill is properly loaded and indicated on the waybills and that all packages are shipped in proper form to insure their safe carriage.

517. At large terminal stations this question of loading becomes a very important factor in the satisfactory operation of the road. A system of loading must be devised so that there will be a cross check on the loading. A suggestion of a scheme is as follows:

Freight is loaded into cars from receiving platforms by truckers, and checked by a loading clerk.

Freight will be received at different doors for different parts of the line.

Each trucker will call out destination and mark of each package as he places it on his truck.

The clerk has blank forms for each trucker, as below; and when the destination is called he writes the number of car and track on the card, records the identification mark, and makes a check after "No." on the blank. No truck will carry packages for more than one car at a time.

Trucker *3*.	
Car *6*.	Track *4*.
Marks *A. B. C.*	No.____
Marks *C. D. E.*	No.____
Marks *F. G.*	No.____

This card is given to the trucker when his truck is loaded, and he leaves the card in a box in the car in which he leaves the packages. These cards are afterwards collected by an inspector and checked back against the waybill. One clerk can card for about four to six truckers. Large signs will be hung in each car, giving car and track numbers, and points for which that car will be loaded, thus:

Car No. 6.
Track No. 4.

Way Stations.
N. Y. City
to
Albany.

Fig. 130 indicates position of tracks for loading at a large station. The cars are run onto the parallel tracks and so "spotted" that the side doors of cars on all six tracks shall be in line, perpendicular to he loading platform. The platform is con-

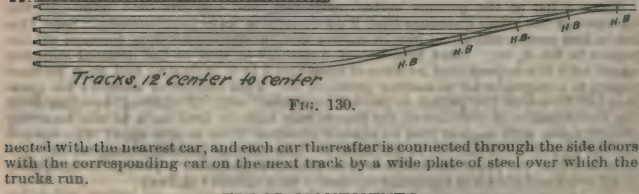


Fig. 130.

nected with the nearest car, and each car thereafter is connected through the side doors with the corresponding car on the next track by a wide plate of steel over which the trucks run.

TROOP MOVEMENTS.

518. **Entraining of troops.**—As soon as a railroad is taken under military control, a bulletin for railway use should be published, giving the capacity of cars, and the maximum number of cars, loaded and empty, to be run in trains, where the whole

tonnage rating of the engines can not be utilized. The carrying capacity of coaches and other cars should be given for both **normal transportation** and **hurried transportation;** the normal transportation will be used unless the other be specifically stated, in which case trains will be made to carry every available man that safety will permit.

519. **Rations** for the men on the train will be carried in the baggage cars, or kitchen cars if provided. Where an entire unit can not be carried on one train, battalions can be broken up and certain companies assigned to one train, while the remainder follow in another. The **assignment of troops** to trains will rest with the railway officials. Where regiments carry tentage and camp equipage, these will normally be sent ahead of the troops in one train and will not be divided up amongst the trains carrying the troops. The baggage of the companies traveling on different trains will be kept separate so that the baggage of each company can be shipped in the train with the company. All **company baggage** will be **plainly marked**, indicating the company and regiment. In infantry regiments, the officers' horses will be shipped ahead, in the train with the camp equipage.

520. In **mounted regiments**, the first trains will carry the horses, with men to look after them. The picket lines and a proper amount of forage will be carried on the horse trains. Guns, caissons, and wagons will follow on trains in the rear of the regiments to which they belong.

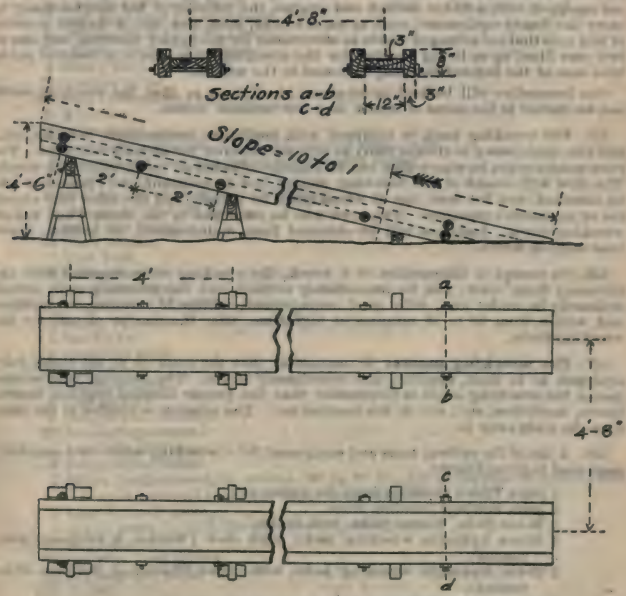


FIG. 131.—PORTABLE RAMPS FOR VEHICLES.

521. In loading artillery wagons on trains, they will be loaded on the cars from a platform or from portable ramps (fig. 131). They will be loaded on one car and run by hand or horse power to the car on which they are to be carried.

The openings between cars will be covered by plates of iron over which the vehicles may run. As soon as a vehicle is on the car, a rope with a hook will be attached

to the wagon; a team of horses on the ground, moving parallel to the train, will pull the vehicle while it is guided by men on the tongue. By this means, loading of heavy vehicles will be greatly facilitated.

522. No officer, soldier, or civilian can travel on the military railway except he be provided with the **proper transportation.** Such transportation will not be issued except upon the presentation of an order authorizing the journey, or granting a leave; and in the case of a civilian, an order from headquarters authorizing him to travel on the military railway.

523. When trains are running through a district **infested by the enemy**, all officers and men traveling by such trains must go **properly armed.** The senior officer on the train is responsible that order is kept on the train and that the regulations are obeyed; and in case of attack, he assumes command during the attack. **In case of disorder** on the train he can call any other officer or soldier to his assistance in maintaining discipline.

WRECKING OUTFITS.

524. The organization and equipment of the **wrecking outfits** on a military road must be complete in every particular. These wrecking outfits will be assigned to certain sections of the line and will be stationed at or near the center of the territory to which they belong. The wrecking outfit proper is composed of a crane car equipped with a 50-ton derrick and engine, the number of flat cars necessary to carry the heavy equipment, such as extra trucks, rails, ties, etc., a certain number of box cars that are arranged inside as storerooms for the lighter material, and one or two cars fitted up as living quarters for the wrecking crew, and as a hospital car to take care of the injured that may be found in the wrecks.

One locomotive will be kept under steam at all times so that the wrecking outfit can be started to the scene of wreck on a few minutes' notice.

525. The wrecking train is equipped with medicines, instruments, bedding, etc., and the commissary is always ready to care for the crew for at least two days. The crew must always be where they can be rapidly collected on notification of a wreck. The crew will consist of one wrecking master and an assistant, one cranesman and an assistant, and five men, one of whom shall be a cook, and the other four expert car or locomotive repairers. This crew will be employed in the shops when not on wrecking work. Laborers will be obtained from maintenance, or section, crews near scene of wreck.

526. On receipt of information of a wreck, the wrecking crew, together with the necessary train crew, will be immediately notified, and the wrecking train should ordinarily be under way, with good management, within 15 minutes, in daytime, and within from 20 to 25 minutes at nighttime, after the receipt of call for the wrecking train.

527. The **wrecking master** is responsible that the train is at all times fully equipped as to tools, supplies, and commissary stores. The surgeon who accompanies the wrecking outfit is responsible that the proper hospital supplies, instruments, medicines, etc., are in the hospital car. The surgeon is notified at the same time the train crew is.

528. A list of the railway tools and equipment for a wrecking outfit on a standard-gage road is given below:

- 2 pairs Tilden rerailing frogs for proper rail.
- 2 pairs Fewings rerailing frogs.
- 2 35-ton 31-in. Norton jacks, with hooks.
- 2 30-ton hydraulic wrecking jacks, with claw (Watson & Stillman 18-in. runout).
- 2 20-ton hydraulic wrecking jacks, with claws (Watson & Stillman 18-in. runout).
- 2 track jacks (Barrett).
- 4 16-in. triple blocks. Two of these blocks, together with one rope, constitute block and fall ready for use, the remaining blocks and rope being held separately as a reserve.
- 4 18-in. double blocks and 2 manila ropes, 2 in. in diameter, each 400 ft. long, rove as 2 blocks and falls.
- 4 12-in. triple blocks, and 2 manila ropes, 1¼ in. in diameter, each 400 ft. long, rove as 2 blocks and falls.

List of the railway tools and equipment for a wrecking outfit—*Continued.*

1 2-in. manila rope 200 ft. long.
1 1¼-in. manila rope 200 ft. long.
2 30-in. snatch blocks
2 18-in. snatch blocks.
2 12-in. snatch blocks.
1 1-in. crucible cast-steel cable 100 ft. long.
1 manila dragrope 6 in. in diameter, 50 ft. long, with hook on one end and link on the other.
2 4-in. manila dragropes 50 ft. long, with hook on one end and link on the other.
2 3-in. manila dragropes 50 ft. long, with hook on one end and link on the other.
2 crucible, cast-steel, 1¾-in. dragropes 40 ft. long, with hook on one end and link on the other. This is intended for special use where large engines have to be handled.
10 bumper chains.
4 ½-in. chains 22 ft. long, with rings on each end, one ring to pass through the other; tested to 70,000 lbs.
6 Crosby cable clamps.
2 crab links for 1½-in. chain.
2 crab links for 1¼-in. chain.
2 crab links for 1-in. chain.
2 crab hooks for 1½-in. chain.
2 crab hooks for 1¼-in. chain.
2 crab hooks for 1-in. chain.
4 heavy hooks and links.
2 hauling links.
4 anchor shackles and pins, 1½-in. iron.
2 S hooks.
2 splice links.
1 singletree cable and L hooks for steam crane only.
Assortment of oval and round thimbles for ropes.
1 16-ft. ladder.
Signal oil and cans, waste, and car oil.
4 gallons alcohol for jacks.
6 pairs rail tongs.
12 track chisels.
6 claw bars.
10 lining bars.
2 hand hammers.
3 18-in. screw wrenches.
3 track wrenches.
2 hand axes.
6 chopping axes.
2 handsaws.
3 crosscut saws.
6 clay picks.
2 sledges and handles.
12 fire extinguishers.
1 pair pole climbers.
4 pairs rubber boots.
2 pieces medium-weight canvas, 20 by 30 ft., for protection of perishable freight removed from cars in stormy weather.
2 kegs of track spikes.
1 keg of track bolts of the sizes used on the division.
1,000 nut locks.
50 lbs. 8-in. boat spikes.
½ keg assorted nails.
200 ft. rail.
80 ties.
6 picks.
1 headlight at base of boom of steam crane.
1 crane push pole.
220 pieces, wedges, etc., for blocking; assorted sizes specified, but omitted here. It is also required that about twice this amount be kept on hand to replenish car (very important).

List of the railway tools and equipment for a wrecking outfit—*Continued.*

2 Pierson jacks and 2 Jeremiah truck levers.
2 long punches for driving out kingbolts.
1 stretcher.
12 hand torches.
6 wrecking torches.
8 white lanterns.
3 Dressel station lights.
2 Sherry lights.
4 cant hooks and handles.
6 grappling hooks and handles.
10 short-handled, round-pointed shovels.
6 scoop shovels.
6 spike mauls.
4 adzes.
1 track gage.
4 pairs extra car trucks.
1 locomotive truck.
1 tank truck.
4 extra car knuckles.
1 extra switch (in some cases).
1 extra frog.
2 extra center plates.
6 kingbolts.
An assortment of wedges and brasses.
6 extra air hoses.
6 coupling links and pins.
2 long crooked pins.
4 fire buckets.
1 wheel gage.
1 complete outfit for cutting in a telegraph station at scene of the wreck.
Hospital equipment as directed by surgeon in charge.

One such wrecking outfit will be supplied for every 100 to 200 miles of line, depending upon the condition of the roadway and the activity of the enemy.

A **track-repair gang** will follow the wrecking train to the scene of the accident as soon as they can be collected, and a bridge-building crew will also be sent out in case a bridge was damaged in the accident.

An assistant superintendent or train master immediately repairs to the scene of the wreck and takes charge of operations.

RAILWAY POLICE.

529. In addition to the troops employed to protect the line of railway, there will be need of a force of railway police. Certain of these policemen, or detectives, will be directly under the A. D. R., and others will be under the division superintendents. The number employed will depend upon the necessities.

The **duties of railway police** are to detect theft from cars, issuance or sale of bogus transportation, interference with the operation of the railway, or destruction of railway property. They will assist in the detection of spies, of employees who illegally transport liquors, or of mail that may have been forbidden by the censor.

ARMY LABOR BUREAU.

530. This bureau has entire charge of the employment of all labor used by the different departments of the army, and the bureau should be organized as soon as the army takes the field. There must be absolutely no competition between the different departments if satisfactory labor conditions are to prevail. The labor situation in the Philippines in 1898–99 sufficiently illustrates this point.

531. Any officer requiring laborers should **apply direct to the bureau**, stating the number and kind desired. The laborers employed by the bureau will be divided into gangs of from 25 to 30 men each, under a foreman. Employment of labor outside the bureau, except in cases of emergency, will be forbidden, and **in no case** should the pay or allowances be more than that paid by the bureau.

MAINTENANCE OF WAY.

532. In a theater of war, with an active enemy, the number of breaks in a railway will be very large. The repairs thus necessitated must be rapidly and effectively accomplished. The **maintenance of way department** must be so organized that it is prepared to repair any break of whatever nature that may occur. This department can not be an economical one from a money standpoint. A large maintenance force must be kept on each division at all times, and during intervals between breaks it may not be possible to utilize the services of these men. The maintenance of way department behind Sherman's army was at times larger than all the other departments of the railway combined.

533. This department on each division will be under the **division engineer**, and for a division of from 100 to 200 miles in length the department must be self-sustaining. For this reason, the division engineer on maintenance and repair matters is directly under the supervision of the division superintendent.

Each division should be subdivided into districts about 100 miles in length, and each such district should be in charge of an assistant engineer.

Such a large force must be employed by the engineer department for rapid reconstruction that no provision is made herein for a maintenance department such as, on civil railways, is in charge of a **roadmaster.**

Maintenance work can be divided into water supply, track, and bridge work. Each of these departments on a 100-mile stretch will be in charge of a supervisor.

534. The **supervisor of water supply** has charge of the installation and repair of all pumping stations, including the boilers, pumps, windmills, and other structures.

The machinery that is installed should have interchangeable parts wherever practicable, and there will be a supply of extra parts on hand at all times.

Tanks for watering stations will be kept knocked down in the storehouses. It may be impracticable to erect the tanks with the regulation supply pipe; for watering the locomotives, a hose or pipe can be used as a siphon to take the water out of the tank. The Emerson pump and the pulsometer pump, referred to in par. 194, are very good for watering stations, since they have very few parts, no wearing parts, and require no foundations.

The supervisor will have under him one foreman and from 6 to 10 mechanics. He will have a car in which is stored parts of a pumping station likely to be destroyed by an enemy. The gasoline motor cars referred to in pars. 116 and 119 will be found useful for his inspection and repair trips.

535. The **supervisor of track** has charge of the maintenance and repair of all track and roadbed.

A large gang of trackmen will be kept together on each division, equipped with tools and supplies, ready to start on short notice to repair the track or the roadbed. When this gang moves to repair a break, they will move in a train consisting of box cars fitted with bunks, and other cars for tools, supplies, and commissary stores. One car will be fitted up as a kitchen car. A few portable forges will be carried with the outfit.

The supervisor is assisted by 1 clerk, 1 timekeeper, a commissary and quartermaster, and a surgeon. He will have 1 foreman, and 3 subforemen to every 60 men. A gang will have about 1 mechanic to every 6 laborers, and 1 cook to every 30 men, 1 for headquarters, and 1 for the foremen's mess. The above makes a flexible organization; it can be worked as a whole, or be subdivided and still retain its efficiency.

In addition to repairing breaks, the supervisor of track has charge of the normal maintenance of the division that is usually called **section work.** He will attend to this duty with his gangs during the intervals between breaks in the line.

536. **Section work.**—A section will comprise from 5 to 7 miles of single track, and, where practicable, the middle of the section will lie at a station. Such a section will be in charge of a section foreman, who will have a gang of from 6 to 8 men on an old road, or 12 to 16 on a new road. The section foreman is responsible for the condition of his section under normal conditions. He will see that the rail joints

are kept up, that the crossings are in repair, that the track is kept in alignment, that bad ties are replaced with good ones, and that a thorough inspection is made of his section as often as the conditions necessitate, and always once a day. He will keep sharp lookout for broken rails, fires on wooden structures, and washouts. During rain storms he will patrol his section and immediately report any danger that may threaten, and will stop all traffic if necessary until proper repairs have been made. He will inspect for and report any break in the telegraph lines. Such section gangs will be detailed and controlled by the supervisor of track.

537. **When replacing broken rails** or making other repairs to the track, section foremen will see that the proper signals are put out to warn trains (see pars. 338 and 356). No tools or appliances will be operated or left between the rails except when necessary.

538. Each section will be supplied with the following **tools and appliances**, for which the section foreman is responsible to the supervisor of track:

Adzes	2	Hammer, striking, 10-lb	1
Augers, post hole	2	Hoes, scuffle or weed	4
Ax, chopping	1	Hooks, brush	2
Ax, hand	1	Jacks, track	2
Bars, claw	4	Keg, water	1
Bars, lining	6	Key, switch	1
Bars, pinch	2	Lanterns (white), complete	4
Bars, tamping	6	Lanterns (red), complete	6
Board, spot	1	Lanterns (green), complete	4
Brace, carpenter's	1	Level, track	1
Brace bits	2	Mauls, spike	4
Brooms	2	Mattocks	2
Car, hand	1	Padlocks	3
Car, push	1	Picks, clay	6
Chains, lock	2	Pail, water	1
Can, oiler	1	Punch, rail	1
Chisels, track	6	Rakes	2
Cups, tin	2	Saw, hand	1
Drill, ratchet	1	Scythes, grass and weed	6
Drill bits	6	Shovels, track	6
File, large flat	2	Shovels, scoop	6
File, hand saw	1	Stretcher, wire-fence	1
Flags, white	2	Sledge	1
Flags, green	2	Spike puller	1
Flags, red	4	Square, steel	1
Gauge, track	1	Tapeline	1
Grindstone, complete	1	Tongs, rail	2
Handle, extra ax	1	Torpedoes	12
Handle, extra adz	1	Wheelbarrow	1
Handles, extra spike maul	2	Whetstones	6
Handles, extra pick	2	Wrenches, track	6
Hammer, claw	1	Wrench, monkey	1
Hammers, spike	4		

539. The quickest way to **replace a line of rails** is to string out the rail along the track, with the necessary angle bars, nuts, and bolts. The rail is replaced on one side at a time. The new rail is bolted together and laid along the outside of the rail to be taken out. The old rails are then removed, a few at a time, and the new rail slid into place and spiked. The old rail is only unspiked a short distance ahead of the new one; and when a train is due the new rail is spiked into position nearly up to the end of the old rail, and at this point a switch rail from a split switch is bolted to the old rail and spiked against the new rail. After the train passes, the switch rail is taken out, and work proceeds as before. This work should usually progress against the current of traffic on double-track work.

540. The **supervisor of bridges** will have charge of the maintenance and repair of all bridges on the section of line assigned to him. These bridges will be either steel, masonry, or wooden. The work on each class of bridge requires a different class of skilled labor, and each will be under a separate head foreman. There will be about three laborers for each skilled mechanic. The ratio of foremen, subforemen,

and cooks will be as in the track gang. The common labor will be allotted to each head foreman as the necessity arises. The requirements of work may demand separate messing and camping arrangements for each class; if so, the necessary arrangements are made by the supervisor. When different gangs work together, the supervisor designates one man as head of the work. The supervisor will thoroughly acquaint himself with all the bridges on his section of line. He will have drawings and complete bills of material for all bridges, so that on notice of a break the proper repair materials can be started without delay.

541. The **organization of the bridge parties** is similar to that of the track gang. The force of assistants to the supervisor of bridges is similiar to that of the supervisor of track. When the parties are working at separate points, he will arrange for separate medical attendants, commissaries, quartermasters, and clerks to suit the circumstances.

The bridge train is similar to the track train, with the addition of timbers, blocking, girders, derrick, and other tools and appliances for rapid bridge work. If conditions justify, one car may be made up as a concrete car and carry a certain amount of concrete materials. The size of the derrick will be determined by the weight of the rolling stock and the weights of the heaviest spans. The wrecking derrick, when not otherwise employed, can be used on bridge work, but on a military road it would be a risky expedient.

FIELD DIVISIONS.

542. As an army advances along a line of railway in pursuit of a retreating enemy, the railway will be found to be more or less destroyed. The duty of the field A. D. R. and his staff is to once more put this line into shape for operation. It has been found impracticable to have the line undergoing repair by one set of officers and officials and have the same line operated by another set of officials; one administration must control both to give efficient service. For this reason a certain station, from 40 to 50 miles in rear of the railhead, is designated as the **transfer station.** The last communication division ends here, and the division from the transfer station to the railhead is known as the **field division.** This transfer station is usually also the **advanced base.**

543. The officer in charge of the field divisions of the railroads leading into the rear of an army is the field A. D. R. This officer is charged both with repairs to the lines and with the operation of the same from the transfer stations to the several railheads. His work on each division is divided into two parts—the operating department and the construction department. For these departments on each line he has a D. A. D. R. and a **constructing engineer,** and the duty of the A. D. R. to coordinate the work of these two officers on each line so as to obtain the best results for all concerned.

The duties of the D. A. D. R. and of his civil assistants are practically the same as those of the D. A. D. R. of a communication division. Local conditions render his division more difficult to operate than the others, but the general rules laid down for them apply to him.

544. The **constructing engineer** is charged with the temporary repairs to the line. After his working parties pass a point in the line, all the railroad in rear should be available for light traffic. The more permanent repairs to the line will be made later by the maintenance department of the communication divisions. In some special cases it may be advisable to make the **permanent repairs immediately,** and this will be the case whenever it is found that a temporary structure will be nearly as difficult to erect as a more permanent one. In such cases the constructing engineer of the field division may be assisted by the employees of the maintenance department from the divisions in rear.

The work of the construction department for the field divisions will be subdivided in the same manner as described under "Maintenance of way" for the communication divisions, and the organization will follow similar lines.

545. **Labor question.**—The bulk of the labor for the field division will be civilian, as it has been found extremely unsatisfactory to trust entirely to soldier labor. The proportion of skilled to unskilled laborers on temporary track work should be about 1 to 7; on the bridges and building repairs, about 1 to 3.

546. The work is carried on at the railhead from a construction train made up as follows from head to rear:

Two flat cars with rails.
Two flat cars with ties.
One flat car with timbers, namely, 12 by 12, 16 by 8, and 18 by 9 ins.
One flat car of tools and supplies.
One box car for finer tools and stores.
Three tourist sleepers for engineer troops.
Three tourist sleepers for laborers.
One combination car for office and officers.
One box car for commissary supplies, etc.
One dynamo car.
One locomotive.
One tank car.
One gondola car for coal.

The office car will be connected by telephone and telegraph with the rear. This train should carry about 6 to 10 days' rations, and an electric-light plant should be carried along to light up the work, especially bridge work, at night.

There will be a **derrick car**, similar to that described in par. 524, near the railhead at all times. This car will be found of the greatest use in reconstructing bridges and removing débris from wrecked structures.

547. The **construction train** will be supplied with the following tools and equipment and, in addition to these, with any other tools or appliances that will materially assist in rapid reconstruction:

Adzes, carpenter's	10
Anvils and blocks	3
Augers, long and short, 3/8 to 3/4 in	100
Axes, hand and felling	30
Axes, pick, helved	350
Angle bars to suit rails	150
Bags, sand	500
Bags, waterproof, for explosives	3
Bar claw (bull's foot)	20
Barrows, wheel, wood	12
Bars, boring and tamping, 1½-in	17
Bars, crow	60
Bars, hold-up	25
Bars, pinch, track	25
Bellows, smith's, with frame	1
Bellows, tinsmith's	2
Billhooks	29
Blocks, iron, for 3½ ins. circumference rope, single and double	3
Blocks, wooden, for 3½ ins. circumference rope, single and double	8
Boards, pine, 20 ft. by 3 ins. to 16 ft. by 1 in., assorted sizes, pieces	120
Bolt ends, 7/8-in	200
Boltheads, 7/8-in	200
Boltheads, 1½-in	100
Bolts and nuts (3/4-in.), 8, 14, 20, 24, 30, and 36 ins. long, of each	100
Bolts and nuts (1/2-in.), 2, 4, and 6 ins. long, of each	75
Bolts and nuts (1/2-in.), 3 and 9 ins. long, of each	100
Bolts and nuts (1½-in.), 30 ins. long	24
Bolts, drift (3/4-in.), 19, 22, and 26 ins. long, of each	100
Bolts, rail (to suit rail)	3,000
Bolts, steel, for bridge ties	1,000
Brushes, No. 8, and liners, 1 and 1½ in, of each	2
Brushes, paint, 6-oz	8
Buckets, galvanized iron	20
Bunting, red, white, and green, yards of each	10
Cans, oil, feeding	8
Canvas, yards	36
Car, push	1
Chests, tool, filled, U. S. Engineer Company, carpenter	2
Chests, tool, filled, U. S. Engineer Company, blacksmith	4
Chest, tool, filled, U. S. Engineer Company, demolition	1
Chisels, brick, 18-in	12

Tools and equipment for construction train—*Continued.*

Chisels, cold		25
Chisels, smith's, round nose and crosscut		25
Chocks for wheels		6
Clamps for track drills		14
Cold sets		50
Coupling screws		5
Crows, jim		5
Dogs, timber, 12, 18, and 24 ins. long		75
Drills, ¾ and 1 in	of each	6
Drills for ratchets, long and short, ⅞ to 2 in		100
Drier, patent	lbs	14
Elbows and T pieces, 1-in., galvanized iron	of each	12
Files, assorted		40
Flags, hand, red, green, and white	of each	20
Forges, smith's, round		2
Gage, wheel		1
Gages, track		14
Gimlets, assorted		12
Glue	lbs	5
Grindstone, general service		1
Hammers, hand and claw		16
Hammers, sledge, 4-lb. to 14-lb		33
Hammers, spiking		50
Hammers, stone		24
Handles for augers		75
Handles for axes and adzes		15
Handles for hammers, spike and hand		200
Handles for tamping picks and pickaxes		150
Hinges, T and butt, assorted	pairs	120
Hose for pumps	lengths	24
Hot sets		20
Iron, bar, round, ⅞, 1, 1¼, and 1½ in	bars	20
Iron, bar, round, ⅜, ½, and ¾ in	bars	50
Iron, bar, round, 3-in	pieces	3
Iron, bar, flat, 6 by 1 to 2 by ¼ in., assorted	bars	24
Irons, expansion		40
Jacks, ratchet pulling		2
Jacks, track (Barrett's)		10
Jacks, Pearson's	pairs	2
Jacks, traversing, 10 to 20 ton		10
Kegs, water, with faucets		2
Ladles, melting		2
Lanterns, hand (red 10, green 10, white 20)		40
Lanterns, tail		4
Lead, bar	lbs	200
Lead, red and white	lbs	168
Levels, field		4
Levels, spirit		13
Locks for switches, with key	sets	6
Machines, boring, with augers		10
Nails, wire, 5 and 6 in	cwt. of each	3
Nails, wire, 1, 1½, 2, and 4 in	cwt. of each	1
Nipples, plugs and sockets, 1-in., galvanized iron, and bibcocks, brass	of each	6
Oil, olive, castor, colza, linseed	gallons of each	5
Oil, paraffin	gallons	30
Padlocks, galvanized iron		6
Pins, split, steel, assorted	gross	1
Piping, galvanized iron, 1-in	running ft	340
Planes, jack and smoothing		3
Plates, fish, special junction (or angle bars)	pairs	36
Poles, iron-shod (for lights and wires)		30
Pumps, lift and force		3
Punches, center		6
Rail saws (each with extra saws and a saw sharpener), "Bryant"		2
Rails cut to fit standard turnouts (frogs Nos. 8 and 10)	of each	4

Tools and equipment for construction train—*Continued.*

Rails, steel, standard T pattern, 24 and 30 ft	of each	80
Ratchets, track drill (Paulus or Q. & C.)		13
Ratchets, fitters		3
Replacers, Fewing's car	sets	2
Rivets, iron (¾-in.), 4½ to 2½ ins., assorted lengths		600
Rivets, iron (⅞-in.), 4 to 2½ ins., assorted lengths		700
Rods, leveling, 6-ft		5
Rope, manila, 3 ins. circumference	coils	2
Rope, manila, 2¼, 2½, and 4½ in	coil of each	1
Rules, carpenter's		12
Saw-sets, hand and crosscut	of each	3
Saws, 26-in., hand, crosscut, and pit		42
Screws, wood, ¾ to 5 in., assorted	gross of each	4 to 10
Screws and washers, galvanized iron, for sheets	gross	2
Sheets, galvanized iron, corrugated, 6 and 10 ft. long	of each	100
Shovels (square-pointed 300, round-pointed 100)		400
Slings, chain (see wrecking outfit)		4
Sockets, reducing, 2 to 1 in. and 1½ to 1 in	of each	6
Solder	lbs	15
Spikes, hand		6
Spikes, iron, 10-in	cwt	3
Spikes, iron, 8-in	cwt	1½
Spikes, rail	kegs	30
Spun yarn, tarred	coils	2
Squares, carpenter's, 6, 9, 12, and 20 in	of each	2 to 4
Steel, blister	lbs	28
Steel, tool, octagonal, ½, ¾, 1, 1¼, and 1½ in. bars	of each	2
Stocks and dies, 2 to 1⅜ in., 1½ to ⅜ in., and 1⅛ to ¼ in.,	set of each	1
Switches and frogs, complete, Nos. 8 and 10	set of each	1
Tallow, Russian	lbs	200
Tamping picks, helved (stone ballast)		100
Tank, water, galvanized iron, 200 gallons		1
Tanks, water, galvanized iron, 50 gallons		3
Tapes, measuring, 100 and 50 ft		12
Tarpaulins		4
Theodolite, level, pair of rods, and chain	of each	1
Ties, crossing		23
Ties, standard		672
Timbers, 18 by 9 ins., from 36 to 20 ft. lengths		10
Timbers, 16 by 8 ins., from 32 to 16 ft. lengths		25
Timbers, 12 by 12 ins., from 36 to 30 ft. lengths		8
Tongs for cold sets	pair	1
Tongs, pipe, 1, 1½, and 2 in	of each	1
Tongs, rail		40
Tools, riveter's:		
Spanners and snaps, ¾ and ⅞ in	of each	6
Hammers, with 30-in. handles		12
Tongs	pairs	4
Drifts, ¾ and ⅞ in	of each	24
Hammers, sledge, 8-lb., with 36-in. handles		6
Turpentine	gallons	5
Twine	balls	12
Vise, standing		1
Washers, iron, 1 by ¼ in		224
Waste, cotton	lbs	50
Wells lights, No. 3		2
Wicks for lamps, hand, tail, and hurricane	per lamp	4
Wrenches, assorted		22
Wrenches, monkey, 12 and 15 in	of each	4
Wrenches, Stillson's, 18-in		6
Wrenches, track		50

548. **Construction wagon train.**—It will frequently be found that all the construction party can not work to advantage on a bridge or a single break at one time, and if there is a wagon train with the construction party, that can go on ahead with a party and supplies, repairs can be made for 5 or 6 miles ahead of the train by

the time that the train can advance. This wagon train ought to consist of from 30 to 40 wagons.

549. A suitable amount of **tentage and camp equipage** must be carried to protect the construction parties from inclement weather, and whenever the parties stop long enough at one point a camp will be formed. This will make the men more comfortable and healthy, both of which tend to make them work better under difficulties.

550. **Night work and lighting.**—Night work, except in bridge construction, is done at a disadvantage. For night work the lighting arrangements should be electric lights if possible. Holophane prismatic globes would be of great advantage, as they do not cast such black shadows as do the lights in ordinary globes. Acetylene lamps have reached a high stage of perfection at the present time, but if used as searchlights they throw a very black shadow. Wells lights (fig 58) give good satisfaction for field use.

551. **Water supply.**—The points made in par. 534 cover the subject of water supply and the repairs to same on the field divisions.

552. **Advance depot.**—An advance depot must be established at some station within 40 or 50 miles of the work, and must be completely stocked with all supplies, tools, and materials that will be needed. This storehouse will have to be moved ahead from time to time so as to be within 40 to 50 miles of the railhead. The available supply of stores and tools must be such that at no time will the work be laid out for lack of either.

553. **All army stores** arriving at the railhead station must be unloaded *immediately* and cars shipped back. If supplies can not be unloaded immediately, the loaded cars must be sent back to the nearest storehouse and the proper person disciplined for blocking the railhead.

554. **Precedence** in trains and supplies will be given to anything that pertains to the construction party, except possibly during an engagement. The temporary construction party will only be called upon to lay additional sidings under cases of great emergency.

555. The following is a **list of the supplies** that Colonel Girouard, Director of Railways in South Africa, took with him to South Africa when he assumed charge of the railways:

(*a*) STORES.

Balks, 14 by 14, and 12 by 12 ins., and timbers from 16 by 8 to 9 by 7 ins	cu. ft	152,000
Bolts, ¾-in., of assorted lengths		4,400
Boltheads and ends, with washers		5,800
Spikes, timber, ⅝-in., 7 to 10 ins. long		12,000
Piping, iron, galvanized, 2, 3, and 4 ins. diameter	running ft	29,000
Collars, flanges, bends, sockets, elbows, tubes, connecting cocks, plugs, valves, and bibcocks for pipes as above	of each	20 to 250
Stocks, taps and dies, pipe tongs, spanners, and vises for pipes as above	of each	4 to 24

(*b*) TOOLS.

A large number of tools of various kinds was ordered, of which the following were the principal ones:

Axes, pick, 5-lb		200
Helves for same		500
Shovels, universal, helved		100
Spades		200
Bars, boring, jumping, and tamping, 1¼ and 1½ in		300
Dogs, sawyer's, straight and cross-ended		5,000
Saws, crosscut, blade 5 ft		50
Wire, steel, telegraph, 7½ B. W. G., assorted	tons	20
Iron, wrought, bars, round and square, assorted sizes	tons	33
Screws, iron, flat-headed, 2 to 5 in	gross	225
Blocks, wood, with sheaves for rope 3, 4½, and 5 ins. circumference, single, double, treble, and snatch		165
Rope, manila, 1½ to 5 ins. circumference	ft	30,000
Jacks, screw, traversing, 6 to 20 ton		30

List of supplies used in Africa—*Continued.*

(*b*) TOOLS—*continued.*

Winches, crab, double purchase, to lift from 25 to 60 cwt		10
Pile drivers, hand, 15-cwt		4
Forges of sorts		12
Well-boring tools, complete, to bore 50 ft	sets	2
Rope, wire, Bullivant's, 1½ to 4½ ins. circumference,	running ft	11,000
Clamps, shackles, thimbles, turn-buckles, nippers, and chain slings for above wire rope	each	2 to 12
Wells lights, with 3 extra burners		10
Cable, interruption, 4-core	miles	2
Pumps, hand and steam		42
Tanks, water, 1,500-gallon		60
Bridges, 50-ft. span		10
Bridges, 30-ft. span		30

556. The following is a list of the **principal stores and tools used** on the railways in South Africa during the first and second years of the war:

STORES.

Asbestos	lbs	386
Bolts and nuts		27,000
Bolts, fish		46,500
Bibcocks		211
Bridge work	bridges	40
Cement	barrels	335
Crossings and points		80
Coal	tons	520
Cocks		300
Candles	lbs	525
Copper	lbs	1,000
Carbide of calcium	lb	½
Dogs, sawyer's		18,000
Detonators		700
Dynamite	lbs	150
Ends, bolt		864
Flanges, pipe		200
Ferrules, tube		500
Fuse	coils	52
Grease	lbs	1,150
Glasses, gage		250
Heads, bolt		6,100
Iron, corrugated, galvanized, sheets	ft	52,000
Iron, bar, peak, etc	tons	94
Links, coupling		250
Lead, red, white, and black	tons	2½
Lead	lbs	1,896
Matches	boxes	432
Nails	tons	5
Nipples		250
Nuts		4,800
Oil	gallons	7,400
Piping	running ft	30,500
Pipes, earthenware, etc		750
Pins, coupling, etc		5,000
Plates, fish		24,250
Pitch	lbs	430
Rope	tons	15
Rails	tons	3,300
Rivets	tons	5
Stays and washers	lbs	3,750
Steel	tons	16
Screws	gross	1,030
Spikes, dog		174,000
Sleepers (ties)		66,000
Sal ammoniac	lbs	60

List of principal stores and tools used in Africa—*Continued.*

STORES—*continued.*

Tubing	running ft	900
Tees		550
Tallow	lbs	1,500
Tin	sheets	110
Timber	cu. ft	52,000
Timber	running ft	833,000
Valves		150
Vises		27
Waste	lbs	3,800
Washers, of sorts		20,000
Zinc	sheets	55

TOOLS.

Axes, felling and hand		150
Augers, screw		950
Braces, ratchet		76
Bars, boring, etc		315
Beaters, plate layer's (tamping picks)		400
Bits for ratchet braces		100
Braces, carpenter's		48
Bits for carpenter's braces		53
Blocks, various		280
Buckets, various		370
Bullivant's gear, complete	set	1
Belting	ft	600
Cans of oil		160
Crowbars		200
Chisels		1,000
Drills, ratchets, clamps, etc		120
Emery cloth	sheets	430
Files, various		1,400
Forges		16
Hammers, various		900
Handles, various		5,800
Hose	running ft	3,200
Jackscrews, etc		52
Lamps, various		270
Levels		55
Lines, various		620
Lines, log	fathoms	1,200
Mallets, carpenter's, etc		132
Needles, sailmaker's, etc		380
Pile drivers, hand and steam		3
Picks		1,900
Pencils, carpenter's		800
Pumps and boilers, complete		7
Pumps		30
Phonophores		28
Rules for carpenters, etc		340
Ramps, rail		24
Shovels		3,000
Saws, various		400
Spanners (bar wrenches)		400
Stone, oil and grind		100
Set saws, cold, etc		110
Stocks and dies		40
Tape measures		60
Tarpaulins		75
Trolleys (small cars)		50
Tongues		140
Tools, chests of, etc		50
Wheelbarrows		200
Winches		16
Wedges, hard wood and iron		540
Wrenches		150

The two foregoing lists furnish about the only available data to guide an officer in his preparation of railway supplies for a campaign. They are too indefinite in many cases to furnish more than a very general guide, but nevertheless they are extremely valuable.

557. **The issue of stores.**—Tools or supplies urgently needed can be issued on receipt of an officer by any storekeeper, who will report to the chief storekeeper. This informal issue applies principally to the advanced bases and, in cases of emergency, to storekeepers along the line in rear. Normally, a requisition should come through the proper division channels.

Storekeepers in making regulations should exercise a wise discretion between expendable and nonexpendable articles, making the amount of paper work as small as possible, and yet be consistent with the regulations.

558. The **storekeeper** of the field division should have at the base storehouse one man in complete charge of all stores, whose duty it is to keep track of issues, receipts, and amount of stock on hand; and one man whose duty it is to promptly fill all requisitions and take charge of and properly store all articles received. Simplicity and promptness must characterize the method of accounting for stores. **Memorandum receipts** will be taken when practicable. This will make receiving officers more careful in the use of the property, and will give a closer line on the disposition of property when the same is lost or expended.

559. One **assistant storekeeper** should be charged with the work of collecting and caring for all tools and stores in use by the construction party.

560. When any considerable amount of army stores have been unloaded at the railhead, they will **not be reloaded** for shipment to the front, except under great emergency, until traffic at that point has become normal. It will be found that less delay will be caused by getting up new shipments than by reloading at or near the railhead, unless very favorable conditions exist as regards sidings, cars, etc.

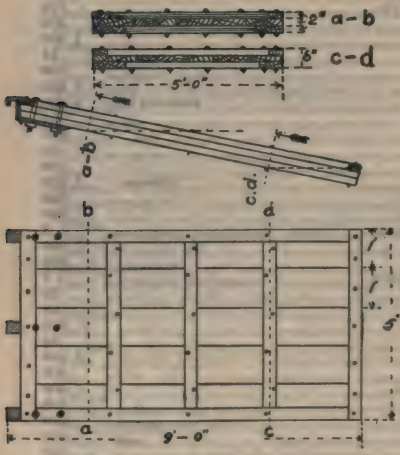


Fig. 132.—Portable animal ramp.

561. **Unloading of troops and animals** at or near the railhead must be expedited in every possible way. Platforms and portable ramps must be supplied at all unloading points. A type of platform and bill of material for same is shown in fig. 108. A portable ramp for vehicles is shown in fig. 131. The method of unloading is just the converse of the method of loading, as described in par. 521. A portable ramp for unloading animals is shown in fig. 132. These can easily be lashed on the truss rods of the cars.

562. **Demolitions.**—The constructing engineer may be called upon to make demolitions in case of retreat. The **lower chords** and **batter posts** of trusses and the abutments and piers of girder bridges are the most open to attack with explosives.

Dynamite and other high explosives are generally used for demolitions and are ignited by an electric exploder. **Abutments** are destroyed by sinking a shaft

behind the masonry, burying a charge at this point, and exploding same by the electric exploder. **Spans** 20 to 60 ft. in length are best destroyed by placing charges at the ends of the truss. This destroys both masonry and truss.

Arches are destroyed by exploding a charge in a shaft sunk from above to the top of the arch or to the haunches.

A **tunnel** is best destroyed by sinking shafts from above and exploding charges to blow in the top of the tunnel. Two trains loaded with railroad iron or other heavy material will effectually close a tunnel if these trains are started at a high speed from opposite ends of the tunnel at the same time and allowed to collide in the middle of the same.

563. A method of **track demolition** recommended by Capt. W. D. Waghorn, R. E., is to blow up alternate joints of rails for several miles, which, he says, would have been much more effective than any form of demolition used by the Boers. (See "Demolitions," Engineer Field Manual, for further details.)

564. In a report on the railroads of the Civil War, an engineer who had great experience in the repair of demolished railways states that in his opinion the most effective way to **demolish a railroad** is to build a fire every 100 ft. along the track on top of the rails. The heat expands the rails and twists them out of shape. The ends of the ties burn off and the resulting demolition is complete. **To repair it**, the twisted mass of wreckage must first be removed, and then the track laid; whereas, if the rails are taken up and bent, only half as much work must be done by the reconstruction party.

565. **Bridges.**—The subject of bridges is dealt with in pars. 123 to 143, which give all the information required for the temporary bridges that will be built.

566. **Cableways.**—In reconstruction work, the use of cableways will be found to facilitate the erection of bridges very greatly; and in cases where a ferry is not practicable, a cableway may be constructed for the transportion of supplies (see par. 143).

Light cableways with a capacity of about 60 tons per hour for spans up to 400 ft. are commercial articles, and from 25 to 30 tons per hour can be carried over a span of 1,000 ft. on a comparatively light cableway.

The **balanced cable crane** appears to have great possibilities, both for construction purposes and for transferring supplies, while a bridge is being constructed.

CONTROL OF TRAINS BY BLOCK SIGNALS.

567. The telegraphic train-dispatching system is so dependent upon the dispatcher, and so many accidents occur through negligence or incompetence, that a system of control known as the block system is used on all first-class roads. For this system each division is divided into blocks, i. e., into lengths of track of defined limits, the use of which by trains is controlled by block signals.

568. A **block signal** is usually a semaphore or a disk, placed on a pole so as to be conspicuous to trains whose movements are governed by it. The **normal position** of all block signals is at **danger** or **stop.**

569. A **home block signal** is a fixed signal at the entrance of a block, to control trains in entering and using said block.

570. A **distant signal** is a fixed signal, used in connection with a home signal to indicate that the home signal may be at "stop" when the distant signal is at "caution," or that the home signal is clear when the distant signal is clear.

571. An **advance block signal** is a fixed signal, used in connection with a home block signal to subdivide the block in advance.

572. A **block station** is an open station where there is a block signal.

573. An **intermediate siding,** as used in block-signal rules, is a siding between block stations, or a siding where the block station is closed.

574. The block system is operated in two ways, viz, the **positive block,** in which only one train at a time is ever allowed in a block, and the **permissive block,** in which, to facilitate train movements, a second train may be admitted into a block by granting the second train a caution card.

575. There are three block systems in use in this country: The **telegraph block system**, the controlled manual block system, and the automatic block system.

The **telegraph block system** is one in which the signals are operated manually, upon information by telegraph.

The **controlled manual block system** is a system in which the signals are operated manually, but are so constructed as to require the cooperation of the signalmen at both ends of the block in order to display a clear signal.

The **automatic block system** is a system in which the signals are operated by electric, pneumatic, or other agency actuated by a train, or by certain conditions affecting the use of a block.

576. The **telegraph block system**, or **manual block system**, is the one that would lend itself most readily to military use. The other systems require apparatus that would undoubtedly be destroyed on a road captured from the enemy, and that could easily be disarranged by a few active spies, or partisans, who knew enough about the system to know how to disable it most seriously.

The block stations will either be connected by telegraph or telephone, and one wire on each division must be allotted for the use of this block system. At all block stations at least a home signal, and if practicable both home and distant signal, will be erected, bearing lights and arms as shown in figs. 133, 134.

It has been found that about 5 miles is the length of block that gives the best results for this system.

577. The movement of trains is regulated by block signals between limits designated by the time-table or by special instructions.

578. Block signals control the use of the blocks but, unless otherwise provided, do not affect the movements of trains under the time-table or train rules nor dispense with the use or observance of other signals whenever or wherever they may be required.

579. Where the semaphore is used, the governing arm is displayed to the right of the signal mast, as seen from the approaching train, and the indications are given by position; the arm in a horizontal position, and in addition at night a red light, when the block is not clear or there are train orders, will indicate **stop**, and will be referred to as a **stop signal.** The arm inclined downward, and in addition at night a green light, when the block is clear or there are no train orders, will indicate **proceed**, the block is clear to the first switch reached at the next block station, and will be referred to as a **clear signal.**

580. Block signals are to be used to control movements of trains upon main track, and must *not* be accepted by trains on sidetracks.

581. **Proper authority** must be obtained from signalman before proceeding, by trains arriving at a block station where signal is at "stop," by trains occupying sidetracks, or by trains starting from terminal stations.

"Proper authority" consists of:

(*a*) A caution card and a release.
(*b*) A release stamped "Block is clear."
(*c*) Train order stamped "Block is clear."
(*d*) Train orders and a caution card.

Trains will be governed as per instructions on caution card, par. 492. This does not relieve the preceding train from compliance with par. 426.

Rules for signalmen.

582. Signalmen will properly record trains, beginning at 12.01 a. m. daily, on **block-register sheets.**

If a train is passed at any station it must be recentered upon the block-register sheet.

The last train entering or leaving a block must be the last recorded.

583. In blocking trains the following code will govern:

"B 2 for _____" signifies "Block all south or east bound trains for _____"
"B 9 for _____" signifies "Block all north or west bound trains for _____."

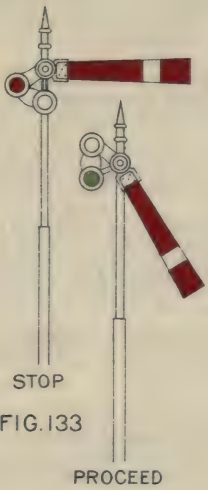


FIG. 133

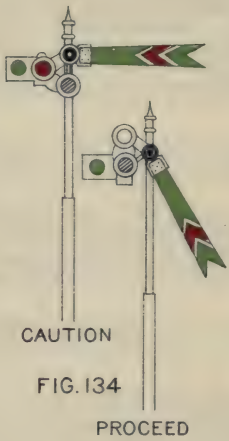


FIG. 134

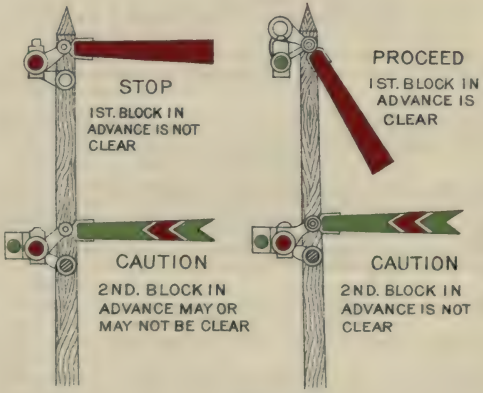


FIG. 135

If a block is clear, a signalman having received "B 2 for _____" or "B 9 for _____," will first enter the train upon his block-register sheet and then reply "I 13 B 2 for _____" or "I 13 B 9 for _____," signing his initials and office call, and will block all opposing trains until the train so admitted has arrived and cleared the block; if the block is not clear, he will reply, "**Block not clear.**"

584. Upon the arrival of a train, signalman will first execute any train orders or block orders he may have, then ascertain from his block register if block is clear, but will not clear his signal until all orders concerning such trains are satisfied and block in advance is clear, and he has received the "13" response, as per code, from next block station in advance.

585. In moving trains in established direction the signalman will, on approach of a train, ascertain from his block register if block is clear, and will not clear his signal until all orders concerning such train are satisfied and block in advance is unoccupied.

586. When there are no train orders and the block ahead is clear for an approaching train, the signal will be changed to "clear" so that the train may enter without reducing speed; and when the train has passed the block signal and the signalman has seen the markers, he must display the stop signal; and when the rear of the train has passed 300 ft. beyond the block signal, he must give train number and the time to the next block station in the rear.

587. Should a train pass a block station **without markers**, the signalman must notify the signalman at the next block station in each direction, and must not report that train clear of the block until he has ascertained that the train is complete.

588. Should a train pass a block station in **two or more parts**, the signalman must notify the signalman at the next block station in advance. A signalman having received this notice must stop any train running in the opposite direction. The stop signal must not be displayed to the engineman of the divided train if the block in advance is clear, but the **train-parted** signal must be given. Should a train going in the opposite direction be stopped, it may be permitted to proceed when it is known that its track is not obstructed.

589. If a train enter a siding at a block station, the signalman must know, or receive notice from the conductor, that it is clear of the main track and switches locked before reporting the block clear.

590. When it is necessary for a train which has been reported as having cleared a block to **reenter the block**, the signalman will proceed the same as in case of an approaching train on single track.

591. Unless directed by special instructions, when two or more trains have been coupled and so run past any block station, they must be uncoupled only at a block station and the signalman notified. When coupled trains have been separated, the signalman must regard each portion as an independent train.

592. To permit a train to **cross over or return**, the signalman must examine the block record; and if all the blocks affected are clear of approaching trains he will arrange with the signalman at the next block station on either side to protect the movement, and when the proper signals have been displayed, cross-over permit may be given. Until the block is clear, no train must be admitted in the direction of the crossover switches except with caution card. **All cross-over movements** must be entered on the block records.

593. A **caution card** is used when trains are permitted to enter a block under notice that such block is not clear. This may be used as follows:

First.—By direction of the train dispatcher, in which event he will send an order of the following form:

"Signalman at _____, issue caution card No. _____, to _____, O. K. _____."

Dispatchers must not authorize operators to issue caution card to any train or engine to enter a block occupied by a passenger train except in case of accident.

Second.—If from the failure of telegraph line or other cause a signalman be unable to communicate with the next block station in advance, he must stop every train approaching in that direction. Should no cause for detaining the train be known, it may then be permitted to proceed, provided 10 minutes have elapsed since the passage of the last preceding train, using caution card, par 492.

When a train is allowed to enter a block under caution card because communication with the signalman in advance can not be had, positive orders will be given by notation on the caution card, directing train and engine men to stop at next station and ascertain the trouble.

594. Should a portion of a train **run back** in the wrong direction, the signalman must notify the next block station toward which the portion of the train is running. The signalman receiving this notice must stop any train running on the same track in the opposite direction, and take such other protective measures as may be practicable.

595. A signalman informed of **any obstruction in a block** must display the stop signal and notify the signalman at the other end of that block. The signalman at the other end of that block must immediately display the stop signal. The clear signal for that block must not be displayed until the obstruction is removed.

596. If necessary to stop a train for which a clear signal has been displayed and accepted, or caution card has been given, the signalman will give hand signals in addition to displaying the stop signal.

597. A signalman will not accept an order to hold a train for train orders, or to block it, after the engine has once passed the signal, until he has succeeded in stopping the train and has communicated with the conductor.

598. A block station must **not be closed** except upon authority of the train dispatcher, nor when trains are approaching which are to meet or pass at that block station.

To **close a block** station, the signalman must first obtain train reports for trains which he has admitted to the blocks in each direction.

He must give notice to the next block station in each direction and transfer the records of the trains in the extended block. He must then enter on his block record the time O. K. of transfer is received from each block station.

The block signals must then be cleared, all lights extinguished, and the block wires arranged to work through the closed station.

599. To **open a block station,** the signalman must give notice to the next block station in each direction and record the trains that are in the extended block. He must then display the normal signal indication and notify the block station in each direction that the station is open.

When trains which were in the extended block when the station was opened, and which had passed his station before it was opened, clear the block in advance, he must repeat the record to the block station in the rear.

600. Signalmen must have torpedoes, fusees, green and red flags, and green, white, and red lanterns, for hand signaling, ready for immediate use. **Hand signals** must not be used when the proper indication can be displayed by the fixed signals. When hand signals are necessary, they must be given from such a point and in such a way that there can be no misunderstanding on the part of the enginemen or trainmen as to the signals, or as to the train or engine for which they are given.

601. When one signalman relieves another, the one going off duty will call the attention of the relieving signalman to all trains in the blocks in which his office is concerned, and obtain the relieving signalman's personal signature on the block-register sheet as his acknowledgment of the transfer.

602. Signalmen must observe, as far as practicable, whether the indication of the signals corresponds with the position of the levers.

603. Signalmen must not make nor permit any unauthorized alterations or additions to the apparatus.

604. Lights must be used upon all block signals from sunset to sunrise and whenever the signal indications can not be clearly seen without them.

Signal rules for enginemen and trainmen.

605. Trains moving under **caution card** must expect to find main track occupied at all stations regardless of the position of block signals.

606. On double track, **cross-over permits** must be obtained before occupying opposite track, except as provided by special instructions issued by the division superintendent, but these permits do not relieve trainmen from compliance with par. 426.

607. A train clearing a block shall not reenter, nor approach within 300 ft. of same, without receiving proper authority from signalman.

608. Trainmen must watch the block signal and be governed by its position until the entire train has passed.

609. At a block station where the **signalman is absent** or incapacitated so that instructions can not be obtained, trains must wait 10 minutes and then proceed with caution to the next block station, where the conductor must report accordingly to the train dispatcher.

610. The train dispatcher will instruct when blocked stations are closed, except as provided by time-table. Trains arriving at such block stations will be governed by instructions received or signal displayed at preceding block station.

611. The engineman of a train which has parted must sound the whistle for **train parted** on approaching a block station.

An engineman receiving a "train parted" signal from a signalman must answer by the whistle signal for "train parted."

When a parted train has been recoupled, the signalman must be notified by the conductor.

612. An engineman holding a caution card (par. 492) must deliver it to the signalman at the next block station and personally ascertain from him that the block in advance is clear before proceeding.

613. Enginemen and trainmen must not accept clear hand signals as against block signals.

614. If the track is obstructed between block stations, notice must be given to the nearest block signalman.

615. Pars. 589 and 591 apply to enginemen and trainmen as well as to signalmen.

616. A train accepting clear signal, intending to proceed to next block station on its rights, but which through delay can not reach such station, must take intermediate siding or protect as per par. 426, in which event superior trains may be given caution card to enter block and proceed on their rights.

617. Two trains scheduled to meet at an intermediate siding shall enter the block as per last half of release, par. 491 (*b*), even though the block signal be clear. Should the inferior train fail to make meeting point, the superior train shall proceed on its time-table rights, under caution.

Where two trains meet by special orders at an intermediate siding, both shall enter the block as per last half of release, par. 491 (*b*).

618. Trains must not go to a closed block station, or nontelegraph station, to be met or passed by other trains without special orders from the train dispatcher, copies of which will be given the operators at the nearest open block signal station on each side of the station where trains are to be passed.

Signalmen receiving such orders will keep their signal at "stop" and issue a release card (par. 491), as per par. 617, or caution card (par. 492), as per par. 616.

Ten-minute block.

619. In blocking trains 10 minutes apart the following must be observed:

In districts not controlled by telegraph block, trains will be blocked 10 minutes apart by train-order signal.

When a train has passed block signal and the signalman has seen the markers, he must display the stop signal and keep it in that position until 10 minutes have elapsed, no exception being allowed unless authorized by train dispatcher in the form of a caution card.

620. When a train is passed by another at a station or intermediate siding, the following train will wait 10 minutes before proceeding.

621. Signalmen will register in their train book arrival and departure of each train, also time that signal was displayed and time that signal was cleared.

Automatic block system.

622. **Explanation of signals.**—The signals used are either the **semaphore** or the **inclosed disk.**

The signal indications are given by not more than two positions of an arm or a disk, and, in addition, at night by lights of prescribed color.

The apparatus is so constructed that the failure of any part directly controlling a signal will cause it to give the normal indication, i. e., danger.

623. The signals, if practicable, are either over or upon the right of and adjoining the track to which they refer. On double track the high signals will be located on the left of and adjoining the track to which they refer. For less than three tracks, the signals for trains in each direction may be attached to the same signal mast.

624. When main running tracks are operated in the same established direction and the space between tracks will not permit of signal masts being located adjoining the track to which they refer, the masts will be located either on a signal bridge or a bracket post.

625. On a bracket post signals on the right-hand mast refer to the main running track farthest to the right; the signals on the next mast to the left refer to the main running track to the left of the first-mentioned track, and so on for each main running track operated in the same established direction.

626. Semaphore arms that govern are displayed to the right of the signal mast as seen from an approaching train.

627. Switches in the main track are so connected with the block signals that the home block signal in the direction of approaching trains will indicate **stop** when the switch is not set for the main track.

628. The signal connections and operating mechanism are so arranged that a home block signal will indicate **stop** after the head of a train shall have passed it.

629. Distant block signals are connected with the corresponding home block signals and so constructed that a train between the distant and home signals, or a switch not set for the main track within the same limits, or the failure of any part controlling the signal, shall cause it to indicate **caution.**

630. Where indicators are placed at the main-track switches, the indicator disk will be visible (through the front opening of the case) when the head of an approaching train has reached a point not less than 1,000 ft. in advance of the block signal protecting the switch.

631. The indications for the main running track are given by a high home signal.

632. Automatic block signals are numbered to indicate the established direction of the running track for which the signal is given, and lettered to denote the district in which they are located.

633. Even-numbered signals govern train movements upon the southbound or eastbound track, and odd-numbered signals upon the northbound or westbound track.

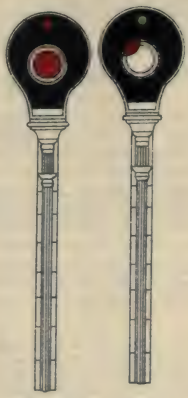
634. **Night signals** are to be displayed from sunset to sunrise. When weather or other conditions obscure day signals, night signals must be used in addition.

RULES.

635. Where the semaphore is used, the governing arm is displayed to the right of the signal mast as seen from an approaching train, and the indications are given by two positions of the arm, and, in addition, at night by lights of prescribed color.

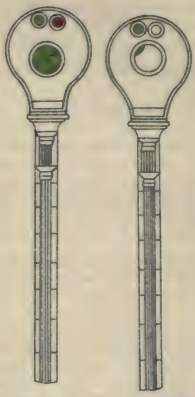
636. Where a single disk is used, the two indications are given by the position of a red or green disk, and, in addition, at night by lights of prescribed color.

637. A **home semaphore signal** (see fig. 133) will display an arm in the horizontal position, and in addition at night a **red** light, when the block is not clear.



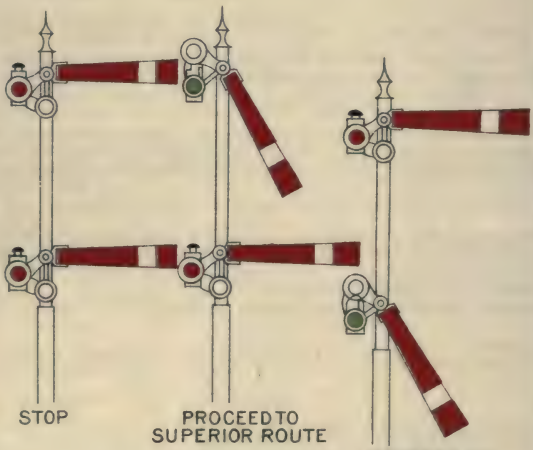
STOP PROCEED

FIG. 136



CAUTION PROCEED

FIG. 137



STOP

PROCEED TO SUPERIOR ROUTE

PROCEED TO INFERIOR ROUTE

FIG. 138

This will indicate **stop,** and will be referred to as a **stop signal.** Or, it will display an arm inclined diagonally downward from the horizontal, and in addition at night a **green** light, when the block is clear. This will indicate **proceed,** and will be referred to as a **clear signal.**

Where two signals are displayed from the same mast, the upper one is the home block signal for the block in advance, and the lower one the distant signal for the second block in advance (see fig. 135).

638. A **distant semaphore signal** (see fig. 134) will display a forked arm in a horizontal position, and in addition at night a **red and green** light, when the home signal with which it is used is at **stop** or the track obstructed between home and distant signal. This will indicate **proceed with caution to the home signal,** and will be referred to as a **caution signal;** or, it will display a forked arm inclined diagonally downward from the horizontal, and in addition at night a **green** light, when the home signal with which it is used is at "clear" and the track unobstructed between home and distant signal. This will indicate **proceed**, and will be referred to as a **clear signal.**

639. A **home disk signal** (see fig. 136) will display a red disk, and, in addition, at night a **red** light, when the block is not clear. This will indicate **stop,** and will be referred to as a **stop signal;** or, the red disk will be withdrawn from view and, in addition, at night a **green** light will be displayed, when the block is clear. This will indicate **proceed,** and will be referred to as a **clear signal.** The face of a home signal case is painted black and the back yellow.

640. A **distant disk signal** (see fig. 137) will display a **green** disk with a **white cross** on its face, and in addition at night a **red and green** light, when the home signal with which it is used is at **stop** or the track obstructed between home and distant signal. This will indicate **proceed with caution to the home signal,** and will be referred to as a **caution signal.**

Or, the disk will be withdrawn from view, and, in addition, at night a **green** light will be displayed, when the home signal with which it is used is "clear" and the track unobstructed between the distant signal and the home signal. This will indicate **proceed,** and will be referred to as a **clear signal.**

The face of a distant signal case is painted white and the back yellow.

641. Block signals control the use of blocks, but, unless otherwise provided, do not affect the movements of trains under the time-table or train rules, nor dispense with the use or the observance of other signals whenever and wherever they may be required.

642. Block signals apply only to trains running in the **established direction.**

643. When a train is stopped by a block signal, it may proceed when the signal is cleared, or after waiting one minute and then running under caution to the next clear signal.

644. When a signal is out of service, the fact will be indicated by a white rectangular shield hung over the number. Trains finding a signal out of service must, unless otherwise directed, proceed with caution to the next signal.

645. When a train is stopped by a signal which is evidently **out of order,** and not so indicated, the fact must be reported to the division superintendent.

646. A signal **imperfectly displayed,** or the absence of one at a place where a signal is usually shown, must be regarded as a danger signal and the fact reported to the division superintendent.

647. The home signal will indicate **"stop"** when the block is occupied, when a switch is set for a siding or a crossover, when a car on a siding fouls the main-line track, when the track circuit is broken, or when the signal is out of order.

648. The **crossover switches** between the main running tracks are so connected with the block signals that the home block signals in the direction of approaching trains will indicate **stop** when either switch of the crossover is not set for the main running track.

649. A switch must not be opened to permit a train movement **to** the main track when the red disk is visible in the indicator box at that switch.

650. A switch may be opened to permit a train movement **from** the main track when the red disk is visible in the indicator box at that switch.

Interlocking plants.

DEFINITIONS.

651. A **high signal** is a signal supported on a mast at a height of at least 20 ft. above the track; it may be a home signal or a distant signal.

A **mast** is an upright to which the signals are directly attached.

A **home signal** is a fixed signal at the point at which trains are required to stop when the route is not clear.

A **distant signal** means the same as the block-signal term.

Dwarf signal. A low home signal.

652. The following are the general principles on which interlocking signals are located and applied:

The **signal** used is the semaphore.

The **indications** are given by not more than two positions of an arm, and in addition at night by lights of prescribed color.

The apparatus is so constructed that the failure of any part directly controlling a signal will cause it to give the normal indication.

652. The signals, if practicable, are either over or upon the right of and adjoining the track to which they refer. On double track the high signals will be located on the left of and adjoining the track to which they refer.

654. The normal indication of a home signal is **stop**, and of a distant signal is **caution**.

The semaphore arms that govern are displayed to the right of the signal mast, as seen from an approaching train.

The apparatus is so constructed that the failure of any part directly controlling a switch or lock will prevent the display of the clear signal.

655. When main running tracks are operated in the same established direction and the space between tracks will not permit of the signal masts being located adjoining the track to which they refer, the masts will be located either on a signal bridge or bracket post.

On a bracket post, signals on the right-hand mast refer to the main running track farthest to the right; the signals on the next mast to the left refer to the main running track to the left of the first-mentioned track, and so on for each main running track operated in the same established direction.

656. When the train service on one main running track is superior to that on another, the signals for that track will be placed 6½ ft. higher on its mast than those for the track of inferior service.

657. The indication for a main running-track movement in the established direction will be given by a high home signal (see fig. 133).

658. The indication for a main running-track movement in the established diverging direction at a junction will be given by one of two signals, located one above the other on the same mast; the topmost signal will govern the superior route and the lower signal that of the secondary or inferior route (fig. 138).

659. The indication for a diverging movement from the main running track in the established direction, to a secondary or side track, will be given by a dwarf signal located on the right of and adjoining the track to which it refers and either at the foot of or opposite the high home signal. The light on the dwarf signal, corresponding to the stop indication, will be shielded off, the high home signal giving the **stop** indication, and the dwarf signal the **proceed** indication, for the diverging movement.

660. The indication for **reverse movement** from the established direction on or from a main running track, or for a movement on a sidetrack in either direction, or from a sidetrack to the main running track, will be given by a dwarf signal.

661. The semaphore arms that govern are displayed to the right of the signal mast, as seen from an approaching train.

662. **Interlocking signals,** unless otherwise provided, do not affect the movements of trains under the time-table or train rules, nor dispense with the use or the observance of other signals whenever and wherever they may be required.

RULES FOR SIGNALMEN.

663. Levers or other operating appliances must be used only by those charged with the duty and as directed by the rules.

Signal levers must be kept in the position giving the normal indication, except when signals are to be cleared for an immediate train or engine movement.

664. When the route is clear, the signals must be cleared sufficiently in advance of approaching trains to avoid delay.

Signals must be restored so as to give the normal indication as soon as the train or engine for which they were cleared has passed the home-signal limits of the interlocking plant.

665. If necessary to **change any route** for which the signals have been cleared for an approaching train or engine, switches must not be changed or signals cleared for any conflicting route until the train or engine for which the signals were first cleared has stopped.

666. A switch or facing-point lock must not be moved when any portion of a train or an engine is standing on or closely approaching the switch or detector bar.

667. Levers must be operated carefully and with a uniform movement. If any irregularity indicating disarranged conditions be detected in their working, the signals must be restored so as to give the normal indication and the connections examined.

During **cold weather** the levers must be moved as often as may be necessary to keep connections from freezing.

If a signal fails to work properly, its operation must be discontinued and the signal secured so as to give the normal indication until repaired.

668. Signalmen must observe, as far as practicable, whether the indication of the signals corresponds with the position of the levers.

669. Signalmen must not make nor permit any unauthorized alterations or additions to the plant.

670. If there is a **derailment,** or if a switch is run through, or if any damage occurs to the track or interlocking plant, the signals must be restored so as to give the normal indication, and no train or switching movement permitted until all parts of the interlocking plant and the track liable to consequent injury have been examined and are known to be in a safe condition.

671. If necessary to disconnect a switch from the interlocking apparatus, the switch must be securely fastened.

672. During storms or drifting snow special care must be used in operating switches. If the force whose duty it is to keep the switches clear is not on hand promptly when required, the fact must be reported to the division superintendent.

673. If any electrical or mechanical appliance fails to work properly, the division superintendent and the district repairman must be notified, and only duly authorized persons permitted to make repairs.

When switches or signals are undergoing repairs, signals must not be given for any movements which may be affected by such repairs until it has been ascertained from the repairmen that the switches are properly set for such movements.

674. Signalmen must observe all passing trains and note whether they are complete and in order. Should there be any indication of conditions endangering the train, or any other train, the signalman must take such measures for the protection of trains as may be practicable.

675. If a signalman has information that an approaching train has parted, he must, if possible, stop trains or engines on conflicting routes, clear the route for the parted train, and give the **train-parted** signal to the engineman.

676. Signalmen must have the proper appliances for **hand signaling** (hand signaling includes the use of lamp, flag, torpedo, and fusee signals) ready for immediate use. Hand signals must not be used when the proper indications can be displayed by the fixed signals. When hand signals are necessary, they must be given from such a point and in such a way that there can be no misunderstanding on the part of enginemen or trainmen as to the signals or as to the train or engine for which they are given.

If necessary to discontinue the use of any fixed signal, hand signals must be used and the division superintendent and the district repairman notified.

677. Signalmen will be held responsible for the care of the interlocking station, lamps, and supplies; and of the interlocking plant, unless provided for otherwise.

678. Lights in interlocking stations must be so placed that they can not be seen from approaching trains.

679. Lights must be used upon all fixed signals from sunset to sunrise, and whenever the signal indications can not be clearly seen without them.

680. If a train or engine overruns a stop signal, the fact, with the number of train or engine, must be reported to the division superintendent and on the daily interlocking report.

681. Only those whose duties require it shall be permitted in the interlocking station.

RULES FOR ENGINEMEN AND TRAINMEN.

682. Trains or engines must be run to but not beyond a signal indicating **stop.**

683. If a clear signal, after being accepted, is changed to a stop signal before it is reached, the stop must be made at once. Such occurrence must be reported to the division superintendent.

684. Enginemen and trainmen must not accept clear hand signals as against fixed signals until they are fully informed of the situation and know that they are protected. Where fixed signals are in operation, trainmen must not give clear hand signals against them.

685. The engineman of a train which has parted must sound the whistle signal for **train parted** on approaching an interlocking station.

An engineman receiving a "train parted" signal from a signalman must answer by the whistle signal for "train parted."

When a parted train has been recoupled, the signalman must be notified.

686. **Sand** must not be used over movable parts of an interlocking plant, and in freezing weather overflow from injectors must not be permitted in such places.

687. Conductors, or enginemen of yard engines, must report to the division superintendent any **unusual detention** at interlocking plants.

688. Trains or engines stopped in making a movement through an interlocking plant must not move in either direction until they have received the proper signal from the signalman.

689. A signal **imperfectly displayed,** or the absence of a signal at a place where a signal is usually shown, must be regarded as a danger signal and the fact reported to the division superintendent.

RULES FOR REPAIRMEN.

690. **Repairmen** are responsible for the inspection, adjustment, and proper maintenance of all the interlocking plants assigned to their care.

Where the condition of switches or track does not admit of the proper operation or maintenance of the interlocking plant the fact must be reported to the division superintendent.

691. When any part of an interlocking plant is to be repaired, a thorough understanding must be had with the signalman in order to secure the safe movement of trains and engines during repairs. The signalman must be notified when the repairs are completed.

692. If necessary to disconnect any switch, it must be securely fastened before any train or engine is permitted to pass over it.

693. **Alterations** or **additions** to an interlocking plant must not be made unless authorized by the signal engineer.

694. Repairmen, when on duty or subject to call, must keep the division superintendent advised as to where they can be found, and respond promptly when called.

DEFENSE OF A LINE OF RAILWAY.

695. The defense of a railway against a brigade or division that may be sent against it for its systematic destruction can only be made by a force of **sufficient** strength to meet and defeat the raiding forces. Besides these attacks by large bodies there are the **continual depredations** against the line made by small bodies ranging from a regiment down to the lone individual who tries to burn a bridge or misplace a switch. The **greatest difficulties** in operating a road come from small bands which can operate against the line, especially in a hostile country, without great danger of apprehension, and these bands must be constantly watched for by a special railway guard.

The defense of the railway must be maintained by the combined use of **blockhouses and armored trains**; neither one alone is sufficient to insure the safety of the line against the attacks of an active enemy.

696. **Blockhouses.**—Blockhouses will be placed at points along the line within sight of one another and about 2,000 or 3,000 yds. apart on tangents, and at all important points, such as bridges, viaducts, and tunnels. The **interval on curves** depends on the radius of the curve and the destructibility of the road in the interval. These blockhouses should be what are commonly known as "Spanish blockhouses," of the type and construction shown in the Engineer Field Manual. Each blockhouse will be built for a garrison of about 16 men; each will be supplied with a good-sized water tank, and will be connected with the other blockhouses by telephone or telegraph. For every three companies of a battalion in the line of blockhouses the fourth company will be stationed at a town in the middle of such line as a support in case of attack; and for every two battalions on the line the third battalion will be held at about the middle point as a reserve. These troops are under the G. C. L. of C.

The track will be **patrolled continually,** both night and day. The patrols should be doubled at night and in inclement weather.

A system of **rocket signals** will be arranged to indicate the presence of the enemy or of an attack by him during the night.

Armored trains.

(Pars. 697 to 724, inclusive, are practically condensed from the History of Railways in the South African war, Royal Engineers' Institute, 1904, altered to suit conditions of the United States service.)

697. Armored trains are made up of an armored locomotive and certain armored and unarmored cars. The general make-up of such a train is shown in fig. 139.

The locomotives should be considerably stronger than the weight of the trains demand, as they are in constant use under adverse circumstances. The locomotive will be covered over its vital parts with **bullet-proof armor** of sheet steel.

The cab, tender, air pump, injector, and other parts, depending upon the make of the engine, that could be injured by bullets at close range, will be protected in like manner. The rear of the cab will be protected from reverse fire, and in the sides of the cab will be placed small hoods with slits, fore and aft; through which the engineman can observe the track in his front and watch for train signals without exposing himself. The sides of the cab will be provided with sliding steel-plate windows.

The boiler need not be armored if it is thick enough to resist rifle fire; otherwise it must be armored also.

The locomotive will be habitually in the middle of the train.

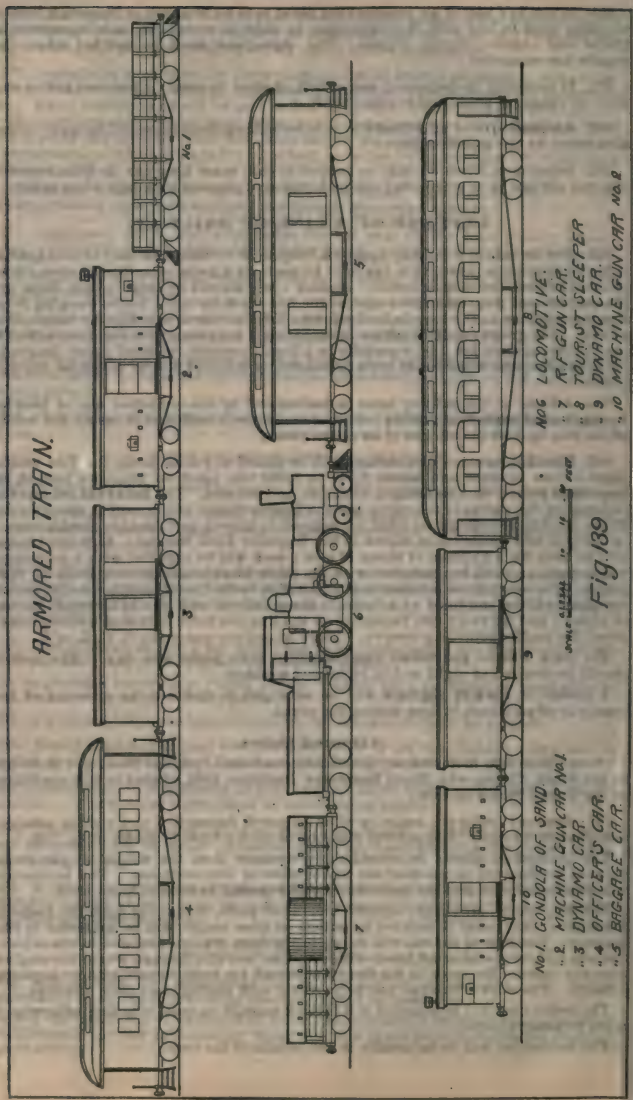

ARMORED TRAIN.
No. 1
No. 6 LOCOMOTIVE.
" 7 R.F. GUN CAR.
" 8 TOURIST SLEEPER
" 9 DYNAMO CAR.
" 10 MACHINE GUN CAR No. 2
No. 1. GONDOLA OF SAND
" 2. MACHINE GUN CAR No. 1.
" 3 DYNAMO CAR.
" 4 OFFICER'S CAR.
" 5 BAGGAGE CAR.

Fig. 139

The **train from front to rear** will be as follows: (1) Gondola loaded with sand; (2) No. 1 machine-gun car; (3) dynamo car; (4) officers' car; (5) baggage car; (6) locomotive; (7) R. F. gun car; (8) such other cars as may be needed in the train; (9) dynamo car; (10) No. 2 machine-gun car.

698. **Searchlights.**—An armored train will be supplied with one, or preferably two, 12-in. searchlights. The dynamo and engine for each of these lights will occupy about half a car. The motive power for the dynamo may be either steam or gasoline. **Gasoline engines** have many advantages, the greatest of which are their independence from a steam generator and the compactness of the plant.

These **dynamo cars** will be run next to the machine-gun cars if gasoline engines are used. Steam from the locomotive can not be used for the motive power, since then the light could only be operated when the locomotive was connected with the dynamo car, and the use of the searchlight, when the armored train was disposed as in fig. 145, would be impossible. Steam engines and boilers take up too much space if other motive power is available. **Direct-connected units** give the best satisfaction and take up the least room. The steam turbine is most compact and noiseless, but requires a steam generator. Gasoline motive power is doubtless the best for this purpose and will be used wherever possible. Direct-connected gasoline sets are now on the market.

699. **Glass mirrors** are commonly used in the projectors, but they are more liable to break than metal mirrors. On the other hand, glass mirrors can be more readily purchased, and if set in rubber will stand considerable jarring. The projector itself will be armored on all sides and will have a sliding door in front. The light can be maneuvered from inside the car by means of a hand or rope control mechanism such as shown in figs. 140 and 141. Electrical-control apparatus is only manufactured for projectors 24 ins. or more in diameter.

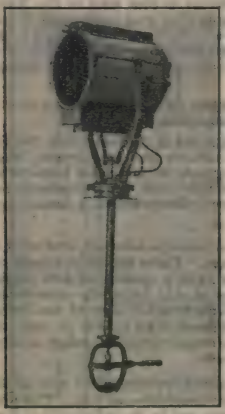


FIG. 140.—PILOT-HOUSE CONTROL PROJECTOR.

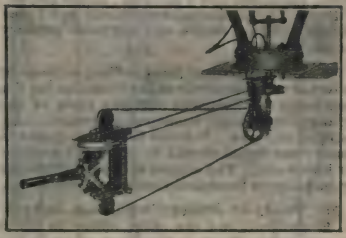


FIG. 141.—ROPE-CONTROL GEAR.

For the 12-in. searchlight a dynamo of about 2 kw. is required. A 12-in. light was found to answer every purpose that was required of it in the South African war.

The searchlights will be located on top of the machine-gun cars, or on the forward machine-gun car if only one light is used. Each searchlight will be provided with a signal shutter similar to the Gibbs shutter used in the Signal Corps. The locomotive should have a searchlight on it for use when the train is disposed as in fig. 145. The turbo-generator sets for this purpose occupy hardly a cubic foot of space, and as an auxiliary light this would be invaluable.

Any extra room in the dynamo cars will be used for bunks for the enlisted men.

The sides of the dynamo car will be plated with ½-in. steel for a height of 7 ft., and the sides will be slotted for rifle fire.

700. A combination diner and sleeper will be utilized for the **officers' car and office.** This car need not be armored unless it is intended to use it as a hospital car. One end of this car will be partitioned off and used as a kitchen for the entire force with the armored train. The telegraph office will also be in this car.

701. The **machine-gun cars** will be armored with ½-in. sheet steel for a height of 7 ft., and provided with loopholes for infantry fire. The general points of their construction are shown in fig. 142.

702. The front car of the train will be a gondola loaded with sand and rigged with a cowcatcher on its forward end. This car is the defense against contact mines.

703. Immediately behind the engine is the R. F. gun car, the general construction of which is shown in figs. 143 and 144, and at the rear of the train is machine-gun car No. 2.

704. It will be necessary to carry a tourist sleeper for the enlisted men and a baggage car for supplies. The position of these cars in the train is shown in fig. 139. A flat car of ties, rails, spikes, etc., for slight repairs will accompany each train.

705. The **side doors** of at least two cars should be so protected that sections can be pushed out about a foot from the car to give a flank fire along the train in both directions (fig. 142).

706. **Armament.**—The main armament of the armored train is a 3-in. R. F. gun, or possibly a 6-pounder, and four machine guns of whatever type may be adopted. The R. F. gun will be placed on a pedestal mount, similar to that used in the Navy, or an adaptation of the pedestal mount with foundation ring and bolts used in our seacoast fortifications. The details of the anchorage are shown in figs. 143 and 144. The ammunition for this gun is carried in the car with the gun. The car will carry about 500 rounds of ammunition. This car is also designed for an infantry defense of about 12 men.

The machine guns may be of any of the approved types, on a tripod or fixed mount. Each gun will be supplied with 30,000 rounds of ammunition.

The **garrison of the armored train** should consist of 2 officers and the following enlisted men: Infantry, 8 noncommissioned officers and 42 privates; engineers, 1 sergeant and 8 privates; signal troops, 1 telegraph lineman and 1 operator; artillery, 3 noncommissioned officers and 7 men; hospital corps, 2 noncommissioned officers. Of the officers, one will be an artillery officer. There will be a double crew for the train.

707. **Communications.**—The cars must all open into one another, and must be provided with platforms to lay from one car to the next. There should be telephonic connection from between different parts of the train, and a system of bell signals arranged in case the telephone is broken. All wires should have slip connections between the cars. It is not feasible to protect all the air-brake system of the train; hence some signal should be arranged to order the release of all brakes in case the air line is cut. The engine will thereafter control the train by its own brakes, assisted by such inside hand-brake arrangements as can be made.

708. **Posts of officers when on duty.**—The artillery officer will ride in the R. F. gun car, and the other officer in the forward machine-gun car. The noncommissioned officers in the other cars will be so instructed in their duties that they can handle their men in action and carry out the intention of the C. O.

709. **Administration of armored trains.**—All armored trains will be under the control of the D. R., and in the immediate charge of an A. D. R. of armored trains, who will order them from one point to another under the direction of the C. of S. of the army. The C. O. of the train, on being ordered to proceed to a certain section of the line, will report to the C. O. of the railway guard of that section, under whose orders he will serve while remaining on that section. He will keep in communication with the A. D. R., and when ordered to another section of the line he will proceed there, after notifying the C. O. on whose section he then is of his new orders.

This makes the armored train a part of the force of the section wherein it is operating; but the general control is kept in the army headquarters, and the trains are handled for the best good of the entire line and not for that of any particular section.

When it is necessary to proceed to any point immediately, the C. O. of the armored train is authorized to inform the train dispatcher of his desires, using the signal

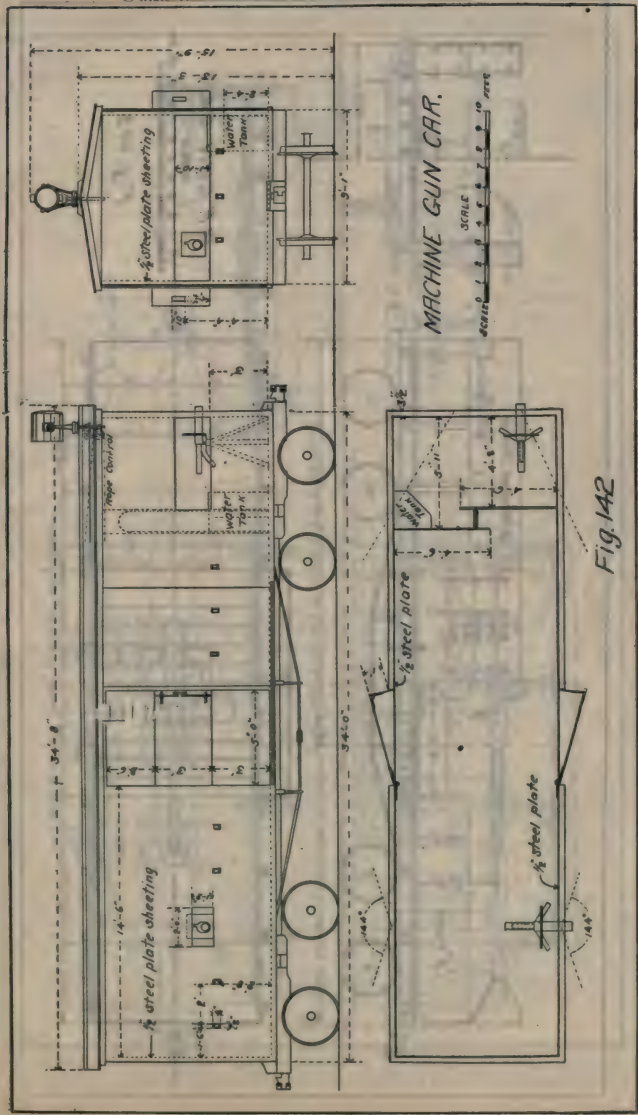
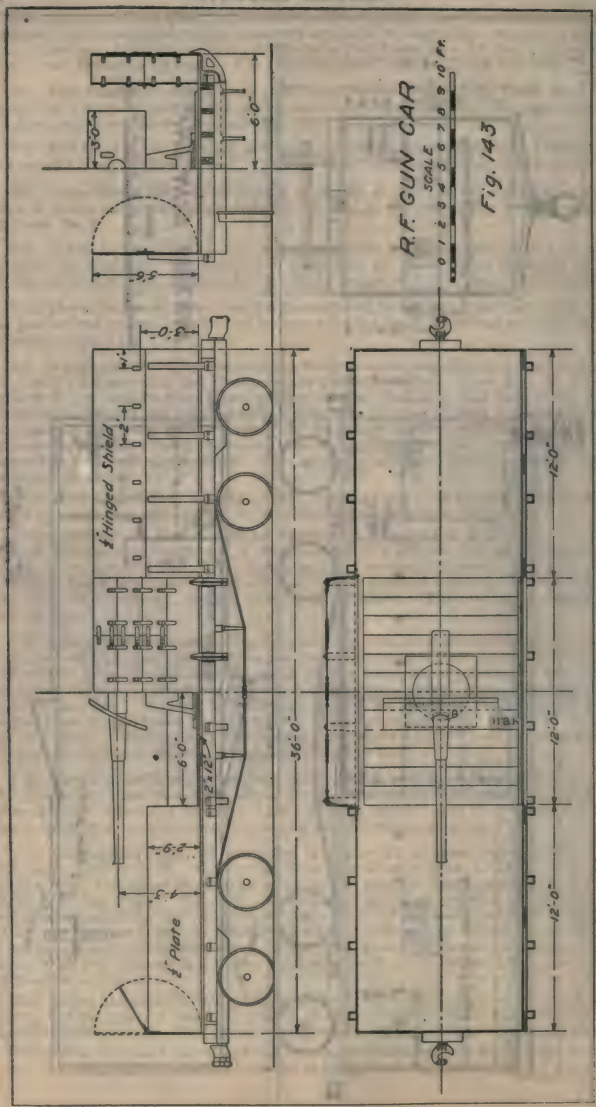

MACHINE GUN CAR.
SCALE
½" steel plate sheeting
Water Tank
Rope Control
½" steel plate
34'-8"
34'-0"
14'-6"
5'-0"
9'-1"
13'-3"
15'-9"
144°

Fig. 142


R.F. GUN CAR
SCALE
0 1 2 3 4 5 6 7 8 9 10 Ft.
Fig. 143
½" Hinged Shield
½" Plate
36'-0"
12'-0"
12'-0"
12'-0"
6'-0"
6'-0"
5'-6"
3'-0"
3'-0"
2'-9"
4'-3"
2"x12"

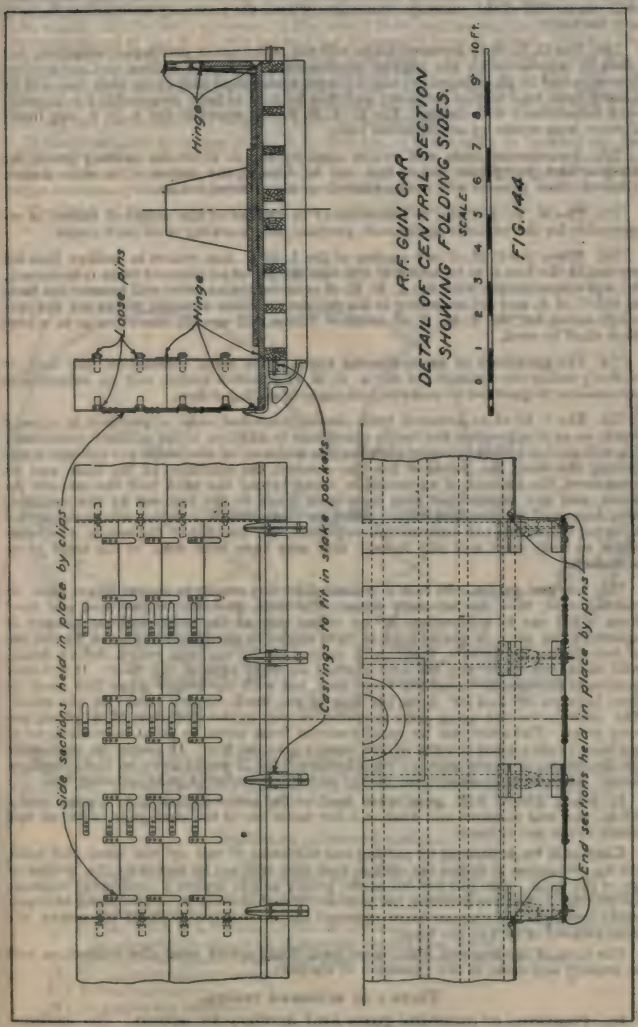

Hinge
Loose pins
Hinge
Side sections held in place by clips
Castings to fit in stake pockets
End sections held in place by pins
R.F. GUN CAR
DETAIL OF CENTRAL SECTION
SHOWING FOLDING SIDES.
SCALE
0 1 2 3 4 5 6 7 8 9 10 Ft.

FIG. 144

"21" to give him immediate right of way over the wires. The train dispatcher will, on receipt of this message, immediately issue the necessary train orders to carry out the move.

710. The C. O. of an armored train will not make use of privileged telegrams, nor shall he interfere with the regular movement of traffic by sudden and unexpected moves except in an emergency; and he must understand that every such case will be passed upon by a higher authority and that he will be held responsible for unnecessary interference with traffic. The D. A. D. R. will report to the A. D. R. any interference with traffic by any armored train.

711. An armored train will not be used by the C. O. of the railway guard for **inspection purposes** unless this can be done in the course of its other duties. Unauthorized persons will not be carried on the armored trains.

712. The A. D. R., who is immediately in charge of the armored trains, is responsible for the efficient equipment, garrison, and working of all such trains.

713. When the C. O. of any section of the L. of C. has reason to believe that his section of the line is to be attacked and that the use of an armored train is necessary, he will communicate with the A. D. R. of armored trains, who will present the facts to the C. of S. and act according to his decision. When armored trains are not specially called for, the A. D. R. of armored trains will use his discretion as to where they shall be used.

714. The **garrison of an armored train,** after being detailed on this duty, is entirely under the command of the A. D. R. of armored trains, and no subordinate commander is qualified to make any changes in such garrison.

715. The C. O. of an armored train should have had some experience in railway work, so as to appreciate the traffic conditions in addition to the military conditions. He will render a weekly report showing the make-up of the train, the mileage made during the week, the points of the line covered, the condition of the train and its armament, the amount of ammunition spent during the week and the amount on hand, and any repairs that may have been made to the railroad by the engineer detachment of the armored train. After an engagement a report will be submitted showing the amount of ammunition expended, the number of the enemy, the casualties on both sides, and any damage that may have been done to the train or its armament.

716. **Larger guns.**—In case it is desired for any reason to mount larger guns on railway cars, this can be easily done. The 6-in. gun can be mounted and fired from a flat car in a direction 30° on either side of the track without danger of upsetting the car. It can be fired at right angles to the line of the track by the use of two girders, or timbers, that can be carried on the car, and which, before firing, will be shoved under the car and blocked up tight against the floor. It is a slow process to traverse and load for every shot, but with the longer guns this must be done between 50° and 90° from the line of the track, to give room for the recoil. The possibilities for using guns mounted on cars in the **defense of a place** are very great. The guns can be rapidly moved from point to point as needed, or to get under cover when the fire of the enemy gets too hot. It would be impossible for the enemy to locate such a "train battery," for it would have no fixed emplacement. It would also deceive the enemy as to the number of guns opposing him.

In South Africa, 6-in. guns were used on flat cars with à 3 ft. 6 in. gage, and a 9.2-in. gun was mounted and fired on a low metal car of the same gage, with no bad result to the car or track.

Cars can be armored by putting one thickness of rail up the sides and ends, taking precaution to fasten the rails so that they will not be moved by the motion or jar of the train. One rail left out at the proper height makes a continuous loophole for rifle fire. By thus utilizing the rails and ties that must be carried along to repair slight breaks in the line, an extra armored car is obtained without increasing the total number of cars in the train.

The C. O. of the armored train must have **judgment and discretion,** as well as bravery and dash, in the execution of his duty.

Tactics of armored trains.

717. **Positions of machine guns and artillery in action.**—The machine-gun cars and the R. F. gun car are self-supporting against a small force of the enemy; any one of them is practically impregnable against infantry fire alone.

The general practice to be adopted against the enemy will be to extend the line by distributing the armored cars along the track such a distance that the rear can not be turned. The cars must be within rifle range of each other, and will be about 1,000 yds. apart. As the train advances, if the enemy is at long range, the train is cut in two just ahead of the R. F. gun car and the locomotive runs on ahead, with the forward part of the train, until within an easy rifle range; here it cuts off the No. 1 machine-gun and dynamo cars, and the locomotive retires to the R. F. gun car. In case the enemy attempts to cut the railroad in rear, the rear section of the train will be backed down the line where the machine-gun car No. 2 is cut off, and the R. F. gun car and the locomotive return to their former position.

If the locomotive is in rear of the R. F. gun car, or if the train is backing up, the train will push up to within easy rifle range, cut off the machine-gun and dynamo cars at that end, and then back down the line and leave the R. F. gun car and the other machine-gun car where it is desired to use them.

The **field of fire and position** of the cars **in action** is shown in fig. 145.

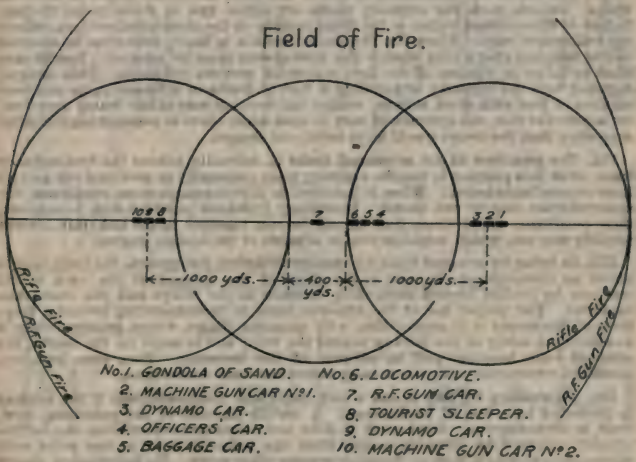


FIG. 145.

In using two or more armored trains together, each train is divided up as described for one train, thus covering a long section of line. The track to the rear is patrolled by the rear locomotive and a machine-gun car, to give notice of any turning movement and prevent the destruction of the track in the rear.

Duties of armored trains.

718. The chief duties of armored trains may be briefly stated as follows:

(1) To intercept and attack a retreating enemy whom the army is driving onto the railroad line.
(2) On the flank of a column or line of columns, the train being well advanced, to prevent the enemy from moving around that flank.
(3) To reenforce stations and camps that are threatened by the enemy.
(4) To escort ordinary trains.
(5) To reconnoiter.
(6) To patrol the railroad.

719. In the first two uses above mentioned, the railway must be divided into sections, each train taking care of a section. Each train should keep moving back and forth, especially at night, over its section. Foot patrols, provided with rockets or fuses, should patrol the track.

Where **blockhouses** are used in conjunction with the armored trains, the system of signals will notify the armored trains in that vicinity of the presence of the enemy. Armored trains should halt at certain prearranged hours, not over 2½ hours apart, and establish telegraphic communication with other armored trains, and with neighboring stations, to give information and receive orders for further movements. In the first use mentioned above, searchlights will not be used unless it is desired to harass the enemy by frightening him into cautious movement. In the second case they will be used to a very great extent.

720. The third use permits of **smaller garrisons** along the line, and of rapid and efficient reenforcement of same.

721. The fourth use mentioned is one of the most important duties of armored trains. On this work the ordinary trains are either run in fleets under the protection of the armored trains, or the latter remain on the threatened sections, escorting trains each way. When the threatened section is short, trains can be escorted one by one, but over a long stretch the fleet system must be adopted. Special care must be taken in the use of the fleet system to prevent collisions. This danger, together with the difficulty of handling a fleet of trains in different yards and over sections of line with short sidings, makes the running rate of the trains very low. On account of this, the system will only be used when there is reasonable ground for supposing that the trains would be in imminent danger.

722. The **position of an armored train** is, normally, behind the first ordinary train, as in this position it has the ordinary train constantly in view and can protect it correspondingly better. When it is desired to give the enginemen confidence, the armored train may be run ahead. If ordinary trains are provided with escort cars, these escort cars of the whole fleet should be run together in the last train, except possibly one car, which might be run in advance of the leading engine.

723. In using an armored train for **reconnoitering purposes**, the train should under no circumstances be sent so far ahead of the troops that the track in the rear can be broken beyond supporting distance of the troops and the train thus captured. The proper use of the armored train in reconnoitering toward a large force of the enemy is in conjunction with mounted troops, whose principal duty is to assure the safety of the railway behind the train and to scout on the flanks, the armored train keeping well in advance of the horsemen. Deep cuts, however, should be reconnoitered by the cavalry before the train enters them.

724. **Patrolling by day** is not a very important duty, especially if the railway is protected by a line of blockhouses. A certain amount of day patrolling, however, is advantageous. Good work is done and important information can be frequently obtained by dropping scouts from the armored train at one point with instructions to join it later at the same or some other point. No information should be given out relative to the position of an armored train at any future hour.

Patrolling by night is one of the most frequent duties of armored trains, for night is the time when the enemy will most frequently attempt to cross or destroy the railway. In patrolling at night, if ordinary traffic is stopped, information should be sent ahead to the stations, ordering switches to be set so that the train can pass through without whistling. Every precaution should be taken to prevent any more noise and light than is absolutely necessary in running the train at a fair rate of speed.

The searchlights should be ready for work at all times. The train need not be on the move all the time in patrolling, as much information can be obtained by lying in a cut or behind a hill and sending out scouts on foot.

The night work just described presupposes that ordinary traffic is suspended during the hours that the armored trains are patrolling the line.

TABLE I.—Number of **crossties** for **1 mile of track.**

Distance c. to c.....ft.	1.5	1.75	2.0	2.25	2.5	2.75	3.0
Number of ties required	3,520	3,018	2,640	2,346	2,112	1,920	1,760

TABLE II—Number of joints for 1 mile of track.

Length of rail.	Number of joints.	Number of bars and bolts for each joint.
30 ft.	352	16 to 65 lb. rails have 2 angle bars and 4 bolts.
Standard practice (90% 30 ft., 10% short).	357.5	70 to 100 lb. rails have 2 angle bars and 6 bolts.
24 ft.	440	
15 ft.	704	

TABLE III.—Number of joints to the ton of rails.

Weight of rail per yard.	Based on 30-ft. lengths.	Based on standard practice, 90% 30 ft., 10% shorts.	Based on 24-ft. lengths.	Based on portable lengths averaging 15 ft.	Weight of rail per yard.	Based on 30-ft. lengths.	Based on standard practice, 90% 30 ft., 10% shorts.	Based on 24-ft. lengths.	Based on portable lengths average ing 15 ft.
Lbs.					*Lbs.*				
100	2.24	2.27	2.80	----------	50	4.48	4.55	5.60	18.96
90	2.49	2.53	3.11	----------	40	5.60	5.69	7.00	11.20
80	2.80	2.84	3.50	----------	30	7.47	7.58	9.33	24.94
70	3.20	3.25	4.00	----------	20	11.20	11.37	14.00	22.40
60	3.73	3.79	4.67	7.46	16	14.00	14.22	17.50	28.00

TABLE IV.—Table for 1 mile, single track.

Rail weight per yard.	Splice bars.		Bolts and nuts.			Spikes.			Weight of total accessories.	Weight of rail.
	No. pairs.	Weight.	Size.	Number.	Weight.	Size.	Number.	Weight.		
Lbs.		*Lbs.*	*Ins.*		*Lbs.*	*Ins.*		*Lbs.*	*Lbs.*	*Tons.*
100	358	29,642	¾ x 4½	2,148	1,953	6 x 5/8	10,560	7,040	38,635	157.14
95	358	27,208	¾ x 4½	2,148	1,953	5½ x 9/16	10,560	5,867	35,028	149.29
90	358	24,701	¾ x 4½	2,148	1,867	5½ x 9/16	10,560	5,867	32,435	141.43
85	358	22,911	¾ x 4½	2,148	1,867	5½ x 9/16	10,560	5,867	30,045	133.57
80	358	21,480	¾ x 4	2,148	1,790	5½ x 9/16	10,560	5,867	29,137	125.71
75	358	20,227	¾ x 4	2,148	1,790	5½ x 9/16	10,560	5,867	27,884	117.86
70	358	19,153	¾ x 3¾	2,148	1,753	5½ x 9/16	10,560	5,867	26,773	110.00
65	358	12,744	¾ x 3¾	1,432	1,169	5½ x 9/16	10,560	5,867	19,780	102.14
60	358	11,706	¾ x 3¾	1,432	1,169	5½ x 9/16	10,560	5,867	18,742	94.29
55	358	10,346	¾ x 3½	1,432	1,146	5½ x 9/16	10,560	5,867	17,359	86.43
50	358	8,628	¾ x 3¼	1,432	1,123	5½ x 9/16	10,560	5,867	15,618	78.57
45	358	5,942	¾ x 3	1,432	1,073	5 x ½	10,560	4,182	11,197	70.71
40	358	4,905	¾ x 3	1,432	1,073	5 x ½	10,560	4,182	10,160	62.86
35	358	4,368	⅝ x 2½	1,432	610	4 x 9/16	10,560	2,708	7,686	55.00
30	358	2,399	⅝ x 2½	1,432	610	4 x 9/16	10,560	2,708	5,717	47.14
25	358	2,041	⅝ x 2¼	1,432	582	4 x 9/16	10,560	2,708	5,331	39.29
20	358	1,611	⅝ x 2¼	1,432	582	3½ x ⅜	10,560	1,689	3,882	31.43
16	358	1,325	⅝ x 2	1,432	546	3½ x ⅜	10,560	1,689	3,560	25.14

Above table is based on standard practice for length of rails, viz., 90% to be 30 ft. and balance of 10% to be not less than 24 ft., varying by 2 ft. Ties 2 ft. c. to c.

Above number of splice bars, bolts and nuts, and spikes allow for no excess.

TABLE V.—Table for 10 tons of rails.

Rail weight per yard.	Splice bars.		Bolts and nuts.			Spikes.			Weight of total accessories.
	No. pairs.	Weight.	Size.	Number.	Weight.	Size.	Number.	Weight.	
Lbs.		*Lbs.*	*Ins.*		*Lbs.*	*Ins.*		*Lbs.*	*Lbs.*
100	23	1,904	3/4 x 4 1/2	138	126	6 x 5/8	672	448	2,478
95	24	1,824	3/4 x 4 1/2	144	131	5 1/2 x 9/16	708	393	2,348
90	25	1,725	3/4 x 4 1/4	150	130	5 1/2 x 9/16	746	414	2,269
85	27	1,728	3/4 x 4 1/4	162	141	5 1/2 x 9/16	790	440	2,309
80	28	1,680	3/4 x 4	168	140	5 1/2 x 9/16	840	467	2,287
75	30	1,695	3/4 x 4	180	150	5 1/2 x 9/16	896	498	2,343
70	33	1,766	3/4 x 3 3/4	198	162	5 1/2 x 9/16	960	533	2,461
65	35	1,246	3/4 x 3 3/4	140	114	5 1/2 x 9/16	1,034	574	1,934
60	38	1,243	3/4 x 3 3/4	152	124	5 1/2 x 9/16	1,120	622	1,989
55	41	1,185	3/4 x 3 1/4	164	131	5 1/2 x 9/16	1,222	680	1,996
50	46	1,109	3/4 x 3 1/4	184	144	5 1/2 x 9/16	1,344	747	2,000
45	51	847	3/4 x 3	204	153	5 x 1/2	1,494	591	1,591
40	57	781	3/4 x 3	228	171	5 x 1/2	1,680	665	1,617
35	65	793	5/8 x 2 1/2	260	111	4 x 7/16	1,920	492	1,396
30	76	509	5/8 x 2 1/2	304	129	4 x 7/16	2,240	574	1,212
25	91	519	5/8 x 2 1/4	364	148	4 x 7/16	2,688	689	1,356
20	114	513	5/8 x 2 1/4	456	185	3 1/2 x 3/8	3,360	538	1,236
16	142	525	5/8 x 2	568	216	3 1/2 x 3/8	4,200	672	1,413

Above table is based on standard practice for length of rails, viz, 90% to be 30 ft. and balance of 10% to be not less than 24 ft., varying by 2 ft. Ties 2 ft. c. to c. Above number of splice bars, bolts and nuts, and spikes allow for no excess.

TABLE VI.—Table of steel spikes.

Size in inches.	Average number per keg of 200 lbs.	Number required and weight per mile, single track.						Rail weight per yard.
		Based on ties 2 ft. c. to c.		Based on ties 2 ft. 6 ins. c. to c.		Based on ties 3 ft. c. to c.		
		Number.	Weight.	Number.	Weight.	Number.	Weight.	
			Lbs.		*Lbs.*		*Lbs.*	*Lbs.*
6 x 5/8 P. R. R.	300	10,560	7,040	8,448	5,632	7,040	4,693	75 to 100
5 1/2 x 9/16	360	10,560	5,867	8,448	4,693	7,040	3,911	45 to 80
5 x 1/2	505	10,560	4,182	8,448	3,345	7,040	2,788	30 to 50
4 x 7/16	780	10,560	2,708	8,448	2,166	7,040	1,805	20 to 35
3 1/2 x 3/8	1,250	10,560	1,689	8,448	1,352	7,040	1,126	16 to 25
2 1/2 x 3/8	1,342	10,560	1,575	8,448	1,260	7,040	1,050	12 to 16

Above numbers allow for no excess.

TABLE VII.—Table of **steel bolts.**

Size, diameter by length under head.	Average number per keg of 200 lbs.	Number required and weight per mile single track for corresponding rail. Based on 30-ft. lengths.		Based on standard practice, 90% 30 ft., 10% in lengths down to 24 ft.		Based on 24-ft. lengths.		Based on portable lengths averaging 15 ft.		Rail weight per yard.
Ins.		*No.*	*Lbs.*	*No.*	*Lbs.*	*No.*	*Lbs.*	*No.*	*Lbs.*	*Lbs.*
7/8 x 4 3/4	140	2,112	3,017	2,148	3,070	2,640	3,771	------	------	100
3/4 x 4 1/2	220	2,112	1,920	2,148	1,953	2,640	2,400	------	------	95 and 100
3/4 x 4 1/4	230	2,112	1,837	2,148	1,867	2,640	2,296	------	------	85 and 90
3/4 x 4	240	2,112	1,760	2,148	1,790	2,640	2,200	------	------	75 and 80
3/4 x 3 3/4	245	2,112	1,724	2.148	1,753	2,640	2,155	------	------	70
3/4 x 3 3/4	245	1,408	1,149	1,432	1,169	1,760	1,437	2,816	2,299	60 and 65
3/4 x 3 1/2	250	1,408	1,126	1,432	1,146	1,760	1,408	2,816	2,253	55
3/4 x 3 1/4	255	1,408	1,104	1,432	1,123	1,760	1,381	2,816	2,208	50
3/4 x 3	267	1,408	1,055	1,432	1,073	1,760	1,318	2,816	2,109	40 and 45
5/8 x 2 1/2	470	1,408	600	1,432	610	1,760	750	2,816	1,198	30 and 35
5/8 x 2 1/4	492	1,408	572	1,432	582	1,760	715	2,816	1,145	20 and 25
5/8 x 2	525	1,408	536	1,432	545	1,760	671	2,816	1,073	16

Threads can be either United States Manufacturer's or Whitworth's standard.
All bolts furnished with hexagon nuts unless otherwise ordered.
Above numbers allow for no excess.

TABLE VIII.—**Weights and dimensions of American standard rail sections.***

Section index.	Weight per yard.	Area.	Width of base and height.	Web.	Width of head.	Height of center of gravity above base.	Axis, $x-x$ † Moment of inertia, I.	Section modulus, S.	Radius of gyration, r.
	Lbs.	*Sq.ins.*	*Ins.*	*Ins.*	*Ins.*	*Ins.*			
100 A	100	9.8	5 3/4	5/16	2 3/4	2.8	43.8	14.6	2.13
90 A	90	8.8	5 3/8	9/16	2 5/8	2.5	34.0	12.0	1.97
80 A	80	7.8	5	35/64	2 1/2	2.4	26.2	10.0	1.83
70 A	70	6.9	4 5/8	33/64	2 1/16	2.2	19.6	8.2	1.70
60 A	60	5.9	4 1/4	31/64	2 5/8	2.1	14.5	6.7	1.58
50 A	50	4.9	3 7/8	7/16	2 1/8	1.9	9.8	4.9	1.42
40 A	40	3.9	3 1/2	25/64	1 7/8	1.7	6.6	3.6	1.30
30 A	30	3.0	3	23/64	1 5/8	1.4	3.5	2.3	1.11
20 A	20	2.0	2 1/2	17/64	1 3/8	1.2	1.7	1.3	.92
16 A	16	1.6	2 1/4	15/64	1 1/4	1.1	1.1	0.97	.84

$$\frac{M}{S} = \frac{\text{Max. bending moment}}{\text{section modulus}} = \text{stress in extreme fiber.}$$

* Am. Soc. C. E. Standard Rail Sections.
† Axis $x-x$ is perpendicular to web of rail section through center of gravity.

TABLE IX.—**Curve formulæ.***

	Given.	Sought.	Formulæ.
1	D	R	$R = \frac{50}{\sin \frac{1}{2} D}$
2	R	D	$\sin \frac{1}{2} D = \frac{50}{R}$
3	$\triangle$, D	L	$L = 100 \frac{\triangle}{D}$
4	D, L	$\triangle$	$\triangle = \frac{DL}{100}$
5	$\triangle$, L	D	$D = 100 \frac{\triangle}{L}$
6	R, $\triangle$	T	$T = R \tan \frac{1}{2} \triangle$
7	"	C	$C = 2R \sin \frac{1}{2} \triangle$
8	"	M	$M = R \text{ vers } \frac{1}{2} \triangle$
9	"	E	$E = R \text{ exsec } \frac{1}{2} \triangle$
10	T, $\triangle$	R	$R = T \cot \frac{1}{2} \triangle$
11	"	E	$E = T \tan \frac{1}{4} \triangle$
12	"	C	$C = 2T \cos \frac{1}{2} \triangle$
13	"	M	$M = T \cot \frac{1}{2} \triangle \cdot \text{vers } \frac{1}{2} \triangle$
14	E, $\triangle$	R	$R = \frac{E}{\text{exsec } \frac{1}{2} \triangle}$
15	"	T	$T = E \cot \frac{1}{4} \triangle$
16	"	C	$C = 2E \frac{\sin \frac{1}{2} \triangle}{\text{exsec } \frac{1}{2} \triangle}$
17	"	M	$M = E \cos \frac{1}{2} \triangle$
18	C, $\triangle$	R	$R = \frac{C}{2 \sin \frac{1}{2} \triangle}$
19	"	M	$M = \frac{1}{2} C \tan \frac{1}{4} \triangle$
20	"	T	$T = \frac{C}{2 \cos \frac{1}{2} \triangle}$
21	"	E	$E = \frac{1}{2} C \frac{\text{exsec } \frac{1}{2} \triangle}{\sin \frac{1}{2} \triangle}$
22	M, $\triangle$	R	$R = \frac{M}{\text{vers } \frac{1}{2} \triangle}$
23	"	C	$C = 2M \cot \frac{1}{4} \triangle$
24	"	T	$T = M \frac{\tan \frac{1}{2} \triangle}{\text{vers } \frac{1}{2} \triangle}$
25	"	E	$E = \frac{M}{\cos \frac{1}{2} \triangle}$

*See par. 16 for meaning of letters.

TABLE IX—**Curve formulæ**—*Continued.*

	Given.	Sought.	Formulæ.
26	R, T	Δ	$\tan \frac{1}{2} \Delta = \frac{T}{R}$
27	"	"	$\sin \frac{1}{2} \Delta = \frac{T}{\sqrt{T^2 + R^2}}$
28	R, C	Δ	$\sin \frac{1}{2} \Delta = \frac{C}{2R}$
29	"	"	$\cos \frac{1}{2} \Delta = \frac{1}{R}\sqrt{\left(R + \frac{C}{2}\right)\left(R - \frac{C}{2}\right)}$
30	R, M	Δ	$\text{vers} \frac{1}{2} \Delta = \frac{M}{R}$
31	"	"	$\cos \frac{1}{2} \Delta = \frac{R - M}{R}$
32	R, E	Δ	$\text{exsec} \frac{1}{2} \Delta = \frac{E}{R}$
33	"	"	$\cos \frac{1}{2} \Delta = \frac{R}{R + E}$
34	T, C	Δ	$\cos \frac{1}{2} \Delta = \frac{C}{2T}$
35	"	"	$\tan \frac{1}{4} \Delta = \sqrt{\frac{2T - C}{2T + C}}$
36	T, E	Δ	$\tan \frac{1}{4} \Delta = \frac{E}{T}$
37	"	"	$\cos \frac{1}{2} \Delta = \frac{T^2 - E^2}{T^2 + E^2}$
38	C, M	Δ	$\tan \frac{1}{4} \Delta = \frac{2M}{C}$
39	"	"	$\cos \frac{1}{2} \Delta = \frac{C^2 - 4M^2}{C^2 + 4M^2}$
40	M, E	Δ	$\cos \frac{1}{2} \Delta = \frac{M}{E}$
41	"	"	$\tan \frac{1}{4} \Delta = \sqrt{\frac{E - M}{E + M}}$
42	R, T	C	$C = \frac{2TR}{\sqrt{T^2 + R^2}}$
43	"	M	$M = R - \frac{R^2}{\sqrt{T^2 + R^2}}$
44	"	E	$E = \sqrt{T^2 + R^2} - R$
45	R, C	T	$T = \frac{CR}{2\sqrt{\left(R + \frac{C}{2}\right)\left(R - \frac{C}{2}\right)}}$
46	"	M	$M = R - \sqrt{(R + \frac{1}{2}C)(R - \frac{1}{2}C)}$
47	"	E	$E = \frac{R^2}{\sqrt{(R + \frac{1}{2}C)(R - \frac{1}{2}C)}} - R$

TABLE IX—**Curve formulæ**—*Continued.*

	Given.	Sought.	Formulæ.
48	R, M	T	$T = \frac{R\sqrt{M(2R - M)}}{R - M}$
49	"	C	$C = 2\sqrt{M(2R - M)}$
50	"	E	$E = \frac{RM}{R - M}$
51	R, E	T	$T = \sqrt{E(2R + E)}$
52	"	C	$C = \frac{2R\sqrt{E(2R + E)}}{R + E}$
53	"	M	$M = \frac{RE}{R + E}$
54	T, C	R	$R = \frac{CT}{\sqrt{(2T + C)(2T - C)}}$
55	"	M	$M = \frac{1}{2}C\sqrt{\frac{2T - C}{2T + C}}$
56	"	E	$E = T\sqrt{\frac{2T - C}{2T + C}}$
57	T, E	R	$R = \frac{(T + E)(T - E)}{2E}$
58	"	C	$C = \frac{2T(T^2 - E^2)}{T^2 + E^2}$
59	"	M	$M = \frac{E(T^2 - E^2)}{T^2 + E^2}$
60	C, M	R	$R = \frac{M^2 + (\frac{1}{2}C)^2}{2M}$
61	"	T	$T = \frac{C(C^2 + 4M^2)}{2(C^2 - 4M^2)}$
62	"	E	$E = M\frac{C^2 + 4M^2}{C^2 - 4M^2}$
63	M, E	R	$R = \frac{EM}{E - M}$
64	"	T	$T = E\sqrt{\frac{E + M}{E - M}}$
65	"	C	$C = 2M\sqrt{\frac{E + M}{E - M}}$
66	T, M	R	$R^3 - R^2\frac{M^2 + T^2}{2M} + RT^2 - \frac{1}{2}MT^2 = 0$
67	"	E	$E^3 + E^2M - ET^2 + MT^2 = 0$
68	"	C	$C^3 + 2TC^2 + 4M^2C - 8M^2T = 0$
69	C, E	R	$R^3 + R^2\frac{4E^2 - C^2}{8E} - R\frac{C^2}{4} - \frac{C^2E}{8} = 0$
70	"	T	$2T^3 - T^2C - 2TE^2 - CE^2 = 0$
71	"	M	$M^3 + M^2E + M\frac{C^2}{4} - \frac{C^2E}{4} = 0$

Table X.—Natural sines, cosines, tangents, and cotangents.

0°–10°

° ′	Sin.	d.	Tan.	d.	Cot.	d.	Cos.	d.		P. P.
0 0	0.0000		0.0000		∞		1.0000		0 90	
10	0.0029	29	0.0029	29	343.773		1.0000	0	50	
20	0.0058	29	0.0058	29	171.885		1.0000	0	40	
30	0.0087	29	0.0087	29	114.588		0.9999	0	30	
40	0.0116	29	0.0116	29	85.9398		0.9999	0	20	
50	0.0145	29	0.0145	29	68.7501		0.9999	0	10	
1 0	0.0174	29	0.0174	29	57.2899		0.9998	0	0 89	
10	0.0203	29	0.0203	29	49.1039	8.1866	0.9998	0	50	30 29 29
20	0.0232	29	0.0233	29	42.9641	6.1398	0.9998	0	40	1 3.0 2.9 2.9
30	0.0262	29	0.0262	29	38.1885	4.7756	0.9997	1	30	2 6.0 5.8 5.8
40	0.0291	29	0.0291	29	34.3677	3.8217	0.9996	1	20	3 9.0 8.8 8.7
50	0.0320	29	0.0320	29	31.2416	3.1261	0.9995	1	10	4 12.0 11.8 11.6
2 0	0.0349	29	0.0349	29	28.6362	2.6053	0.9994	1	0 88	5 15.0 14.7 14.5
10	0.0378	29	0.0378	29	26.4316	2.2046	0.9993	1	50	6 18.0 17.7 17.4
20	0.0407	29	0.0407	29	24.5417	1.8898	0.9991	1	40	7 21.0 20.6 20.3
30	0.0436	29	0.0436	29	22.9037	1.6380	0.9990	1	30	8 24.0 23.6 23.2
40	0.0465	29	0.0466	29	21.4704	1.4333	0.9989	1	20	9 27.0 26.5 26.1
50	0.0494	29	0.0495	29	20.2055	1.2648	0.9988	1	10	
3 0	0.0523	29	0.0524	29	19.0811	1.1244	0.9986	1	0 87	
10	0.0552	29	0.0553	29	18.0750	1.0061	0.9984	2	50	
20	0.0581	29	0.0582	29	17.1693	0.9056	0.9983	1	40	28 5 4 4
30	0.0610	29	0.0611	29	16.3498	0.8195	0.9981	2	30	1 2.8 0.5 0.4 0.4
40	0.0639	29	0.0641	29	15.6048	0.7456	0.9979	2	20	2 5.6 1.0 0.9 0.8
50	0.0668	29	0.0670	29	14.9244	0.6804	0.9977	2	10	3 8.4 1.5 1.3 1.2
4 0	0.0697	29	0.0699	29	14.3006	0.6237	0.9975	2	0 86	4 11.4 2.0 1.8 1.6
10	0.0726	29	0.0728	29	13.7267	0.5739	0.9973	2	50	5 14.2 2.5 2.2 2.0
20	0.0755	29	0.0758	29	13.1969	0.5298	0.9971	2	40	6 17.1 3.0 2.7 2.4
30	0.0784	29	0.0787	29	12.7062	0.4907	0.9969	2	30	7 19.9 3.5 3.1 2.8
40	0.0813	29	0.0816	29	12.2505	0.4557	0.9967	2	20	8 22.8 4.0 3.6 3.2
50	0.0842	29	0.0845	29	11.8261	0.4243	0.9964	2	10	9 25.6 4.5 4.0 3.6
5 0	0.0871	29	0.0875	29	11.4300	0.3961	0.9962	2	0 85	
10	0.0900	29	0.0904	29	11.0594	0.3706	0.9959	3	50	
20	0.0929	29	0.0933	29	10.7119	0.3475	0.9956	3	40	
30	0.0958	29	0.0963	29	10.3854	0.3265	0.9954	3	30	
40	0.0987	29	0.0992	29	10.0780	0.3073	0.9951	3	20	3 3 2 2
50	0.1016	29	0.1021	29	9.7881	0.2899	0.9948	3	10	1 0.3 0.3 0.2 0.2
6 0	0.1045	28	0.1051	29	9.5143	0.2738	0.9945	3	0 84	2 0.7 0.6 0.5 0.4
10	0.1074	29	0.1080	28	9.2553	0.2590	0.9942	3	50	3 1.0 0.9 0.7 0.6
20	0.1103	29	0.1110	29	9.0098	0.2454	0.9939	3	40	4 1.4 1.2 1.0 0.8
30	0.1132	29	0.1139	29	8.7769	0.2329	0.9935	3	30	5 1.7 1.5 1.2 1.0
40	0.1161	29	0.1169	29	8.5555	0.2213	0.9932	3	20	6 2.1 1.8 1.5 1.2
50	0.1190	29	0.1198	29	8.3449	0.2106	0.9929	3	10	7 2.4 2.1 1.7 1.4
7 0	0.1218	28	0.1228	29	8.1443	0.2006	0.9925	3	0 83	8 2.8 2.4 2.0 1.6
10	0.1247	29	0.1257	29	7.9530	0.1913	0.9922	3	50	9 3.2 2.7 2.2 1.8
20	0.1276	29	0.1287	29	7.7703	0.1826	0.9918	4	40	
30	0.1305	29	0.1316	29	7.5957	0.1746	0.9914	3	30	
40	0.1334	29	0.1346	30	7.4287	0.1670	0.9910	4	20	
50	0.1363	29	0.1376	29	7.2687	0.1599	0.9906	4	10	1 1 0
8 0	0.1391	28	0.1405	29	7.1153	0.1534	0.9902	4	0 82	1 0.1 0.1 0.0
10	0.1420	29	0.1435	30	6.9682	0.1471	0.9898	4	50	2 0.3 0.2 0.1
20	0.1449	29	0.1465	30	6.8269	0.1413	0.9894	4	40	3 0.4 0.3 0.1
30	0.1478	29	0.1494	29	6.6911	0.1358	0.9890	4	30	4 0.6 0.4 0.2
40	0.1507	29	0.1524	30	6.5605	0.1306	0.9886	4	20	5 0.7 0.6 0.2
50	0.1536	29	0.1554	30	6.4348	0.1257	0.9881	4	10	6 0.9 0.6 0.3
9 0	0.1564	28	0.1584	30	6.3137	0.1211	0.9877	4	0 81	7 1.0 0.7 0.3
10	0.1593	29	0.1613	29	6.1970	0.1167	0.9872	5	50	8 1.2 0.8 0.4
20	0.1622	29	0.1643	30	6.0844	0.1126	0.9867	4	40	9 1.3 0.9 0.4
30	0.1650	28	0.1673	30	5.9757	0.1087	0.9863	5	30	
40	0.1679	29	0.1703	30	5.8708	0.1049	0.9858	5	20	
50	0.1708	29	0.1733	30	5.7693	0.1014	0.9853	5	10	
10 0	0.1736	28	0.1763	30	5.6713	0.0980	0.9848	5	0 80	
	Cos.	d.	Cot.	d.	Tan.	d.	Sin.	d.	′ °	P. P.

80°–90°

TABLE X.—**Natural sines, cosines, tangents, and cotangents**—*Continued.*

10°-20°

° ′	Sin.	d.	Tan.	d.	Cot.	d.	Cos.	d.	
10 0	0.1736	28	0.1763	29	5.6713	949	0.9848	5	0 80
10	0.1765	28	0.1793	30	5.5764	919	0.9843	5	50
20	0.1793	29	0.1823	30	5.4845	890	0.9838	5	40
30	0.1822	28	0.1853	30	5.3955	862	0.9832	5	30
40	0.1851	28	0.1883	30	5.3093	836	0.9827	5	20
50	0.1879	28	0.1913	30	5.2256	811	0.9822	5	10
11 0	0.1908	28	0.1944	30	5.1445	787	0.9816	6	0 79
10	0.1936	28	0.1974	30	5.0658	764	0.9810	6	50
20	0.1965	28	0.2004	30	4.9894	746	0.9805	6	40
30	0.1993	28	0.2034	30	4.9151	721	0.9799	6	30
40	0.2022	28	0.2065	30	4.8430	701	0.9793	6	20
50	0.2050	28	0.2095	30	4.7728	682	0.9787	6	10
12 0	0.2079	28	0.2125	30	4.7046	664	0.9781	6	0 78
10	0.2107	28	0.2156	30	4.6382	646	0.9775	6	50
20	0.2136	28	0.2186	30	4.5736	629	0.9769	6	40
30	0.2164	28	0.2217	30	4.5107	613	0.9763	6	30
40	0.2193	28	0.2247	30	4.4494	597	0.9756	6	20
50	0.2221	28	0.2278	30	4.3897	582	0.9750	6	10
13 0	0.2249	28	0.2308	30	4.3315	568	0.9743	6	0 77
10	0.2278	28	0.2339	31	4.2747	553	0.9737	6	50
20	0.2306	28	0.2370	30	4.2193	540	0.9730	6	40
30	0.2334	28	0.2401	31	4.1653	527	0.9723	7	30
40	0.2363	28	0.2431	30	4.1125	515	0.9717	6	20
50	0.2391	28	0.2462	31	4.0610	502	0.9710	7	10
14 0	0.2419	28	0.2493	30	4.0108	491	0.9703	7	0 76
10	0.2447	28	0.2524	31	3.9617	480	0.9696	7	50
20	0.2475	28	0.2555	31	3.9136	469	0.9688	7	40
30	0.2504	28	0.2586	31	3.8667	458	0.9681	7	30
40	0.2532	28	0.2617	31	3.8208	449	0.9674	7	20
50	0.2560	28	0.2648	31	3.7759	439	0.9666	7	10
15 0	0.2588	28	0.2679	31	3.7326	429	0.9659	8	0 75
10	0.2616	28	0.2710	31	3.6891	420	0.9651	7	50
20	0.2644	28	0.2742	31	3.6470	412	0.9644	7	40
30	0.2672	28	0.2773	31	3.6059	403	0.9636	8	30
40	0.2700	28	0.2804	31	3.5655	394	0.9628	8	20
50	0.2728	28	0.2836	31	3.5261	387	0.9620	8	10
16 0	0.2756	28	0.2867	31	3.4874	379	0.9612	8	0 74
10	0.2784	28	0.2899	31	3.4495	372	0.9604	8	50
20	0.2812	28	0.2930	31	3.4123	364	0.9596	8	40
30	0.2840	27	0.2962	32	3.3759	357	0.9588	8	30
40	0.2868	28	0.2994	31	3.3402	350	0.9580	8	20
50	0.2896	28	0.3025	32	3.3052	343	0.9571	9	10
17 0	0.2923	27	0.3057	32	3.2708	337	0.9563	8	0 73
10	0.2951	28	0.3089	32	3.2371	331	0.9554	9	50
20	0.2979	28	0.3121	32	3.2046	324	0.9546	8	40
30	0.3007	27	0.3153	32	3.1716	319	0.9537	9	30
40	0.3035	28	0.3185	32	3.1397	313	0.9528	9	20
50	0.3062	27	0.3217	32	3.1084	307	0.9519	9	10
18 0	0.3090	28	0.3249	32	3.0777	302	0.9510	9	0 72
10	0.3118	27	0.3281	32	3.0475	296	0.9501	9	50
20	0.3145	27	0.3313	32	3.0178	291	0.9492	9	40
30	0.3173	27	0.3346	32	2.9887	285	0.9483	9	30
40	0.3200	27	0.3378	32	2.9602	281	0.9474	9	20
50	0.3228	27	0.3411	32	2.9319	277	0.9464	10	10
19 0	0.3255	27	0.3443	32	2.9042	272	0.9455	9	0 71
10	0.3283	27	0.3476	33	2.8770	267	0.9445	9	50
20	0.3310	27	0.3508	32	2.8502	263	0.9436	10	40
30	0.3338	27	0.3541	33	2.8239	259	0.9426	10	30
40	0.3365	27	0.3574	33	2.7980	254	0.9416	10	20
50	0.3393	27	0.3607	32	2.7725	250	0.9407	10	10
20 0	0.3420		0.3639		2.7475		0.9397		0 70
	Cos.	d.	Cot.	d.	Tan.	d.	Sin.	d.	′ °

P. P.

	33	32	31
1	3.3	3.2	3.1
2	6.6	6.4	6.2
3	9.9	9.6	9.3
4	13.2	12.8	12.4
5	16.5	16.0	15.5
6	19.8	19.2	18.6
7	23.1	22.4	21.7
8	26.4	25.6	24.8
9	29.7	28.8	27.9

	30	29
1	3.0	2.9
2	6.0	5.8
3	9.0	8.7
4	12.0	11.6
5	15.0	14.5
6	18.0	17.4
7	21.0	20.3
8	24.0	23.2
9	27.0	26.1

	28	27
1	2.8	2.7
2	5.6	5.4
3	8.4	8.1
4	11.2	10.8
5	14.0	13.5
6	16.8	16.2
7	19.6	18.9
8	22.4	21.6
9	25.2	24.3

	10	9	8
1	1.0	0.9	0.8
2	2.0	1.8	1.6
3	3.0	2.7	2.4
4	4.0	3.6	3.2
5	5.0	4.5	4.0
6	6.0	5.4	4.8
7	7.0	6.3	5.6
8	8.0	7.2	6.4
9	9.0	8.1	7.2

	7	6	5
1	0.7	0.6	0.5
2	1.4	1.2	1.0
3	2.1	1.8	1.5
4	2.8	2.4	2.0
5	3.5	3.0	2.5
6	4.2	3.6	3.0
7	4.9	4.2	3.5
8	5.6	4.8	4.0
9	6.3	5.4	4.5

P. P.

70°-80°

TABLE X.—**Natural sines, cosines, tangents, and cotangents**—*Continued.*

20°-30°

° ′	Sin.	d.	Tan.	d.	Cot.	d.	Cos.	d.		P. P.
20 0	0.3420	27	0.3639	33	2.7475	247	0.9397	10	0 70	
10	0.3447	27	0.3672	33	2.7228	242	0.9387	10	50	
20	0.3475	27	0.3705	33	2.6985	239	0.9377	10	40	
30	0.3502	27	0.3739	33	2.6746	235	0.9366	10	30	
40	0.3529	27	0.3772	33	2.6511	232	0.9356	10	20	39 38 37 36
50	0.3556	27	0.3805	33	2.6279	228	0.9346	10	10	1 3.9 3.8 3.7 3.6
21 0	0.3583	27	0.3838	33	2.6051	225	0.9336	10	0 69	2 7.8 7.6 7.4 7.2
10	0.3611	27	0.3872	33	2.5826	222	0.9325	10	50	3 11.7 11.4 10.1 10.8
20	0.3638	27	0.3905	33	2.5604	218	0.9315	10	40	4 15.6 15.2 14.8 14.4
30	0.3665	27	0.3939	33	2.5386	215	0.9304	10	30	5 19.5 19.0 18.5 18.0
40	0.3692	27	0.3972	34	2.5171	212	0.9293	11	20	6 23.4 22.8 22.2 21.6
50	0.3719	27	0.4006	34	2.4959	208	0.9282	10	10	7 27.3 26.6 25.9 25.2
22 0	0.3746	27	0.4040	33	2.4751	206	0.9272	11	0 68	8 31.2 30.4 29.6 28.8
10	0.3773	27	0.4074	34	2.4545	203	0.9261	11	50	9 35.1 34.2 33.3 32.4
20	0.3800	27	0.4108	34	2.4342	[illegible]	0.9250	11	40	
30	0.3827	26	0.4142	34	2.4142	197	0.9239	11	30	35 35 34 33
40	0.3853	27	0.4176	34	2.3945	194	0.9227	12	20	1 3.5 3.5 3.4 3.3
50	0.3880	27	0.4210	34	2.3750	192	0.9216	11	10	2 7.1 7.0 6.8 6.6
23 0	0.3907	26	0.4244	34	2.3558	189	0.9205	12	0 67	3 10.6 10.5 10.2 9.9
10	0.3934	27	0.4279	34	2.3369	187	0.9193	12	50	4 14.2 14.0 13.6 13.2
20	0.3961	26	0.4313	34	2.3182	184	0.9182	11	40	5 17.7 17.5 17.0 16.5
30	0.3987	26	0.4348	33	2.2998	182	0.9170	12	30	6 21.3 21.0 20.4 19.8
40	0.4014	27	0.4383	34	2.2816	179	0.9159	12	20	7 24.8 24.5 23.8 23.1
50	0.4041	26	0.4417	35	2.2637	177	0.9147	12	10	8 28.4 28.0 27.2 26.4
24 0	0.4067	26	0.4452	34	2.2460	175	0.9135	12	0 66	9 31.9 31.5 30.6 29.7
10	0.4094	26	0.4487	35	2.2285	172	0.9123	12	50	
20	0.4120	26	0.4522	35	2.2113	170	0.9111	12	40	27 27 26 25
30	0.4147	26	0.4557	35	2.1943	168	0.9099	12	30	1 2.7 2.7 2.6 2.5
40	0.4173	26	0.4592	35	2.1775	166	0.9087	12	20	2 5.4 5.4 5.2 5.0
50	0.4200	26	0.4627	35	2.1609	164	0.9075	12	10	3 8.2 8.1 7.8 7.5
25 0	0.4226	26	0.4663	35	2.1445	162	0.9063	12	0 65	4 11.0 10.8 10.4 10.0
10	0.4252	26	0.4698	35	2.1283	159	0.9050	12	50	5 13.7 13.5 13.0 12.5
20	0.4279	26	0.4734	36	2.1123	158	0.9038	12	40	6 16.5 16.2 15.6 15.0
30	0.4305	26	0.4770	35	2.0965	156	0.9026	12	30	7 19.2 18.9 18.2 17.5
40	0.4331	26	0.4805	36	2.0809	154	0.9013	13	20	8 22.0 21.6 20.8 20.0
50	0.4357	26	0.4841	36	2.0655	152	0.9000	12	10	9 24.7 24.3 23.4 22.5
26 0	0.4383	26	0.4877	36	2.0503	150	0.8988	13	0 64	
10	0.4410	26	0.4913	36	2.0352	148	0.8975	12	50	14 14 13 12
20	0.4436	26	0.4949	36	2.0204	147	0.8962	13	40	1 1.4 1.4 1.3 1.2
30	0.4462	26	0.4986	36	2.0057	145	0.8949	13	30	2 2.9 2.8 2.6 2.4
40	0.4488	26	0.5022	36	1.9911	143	0.8936	13	20	3 4.3 4.2 3.9 3.6
50	0.4514	26	0.5058	37	1.9768	142	0.8923	13	10	4 5.8 5.6 5.2 4.8
27 0	0.4540	26	0.5095	36	1.9626	140	0.8910	13	0 63	5 7.2 7.0 6.5 6.0
10	0.4566	25	0.5132	37	1.9486	139	0.8897	13	50	6 8.7 8.4 7.8 7.2
20	0.4591	26	0.5169	36	1.9347	137	0.8883	14	40	7 10.1 9.8 9.1 8.4
30	0.4617	26	0.5205	37	1.9210	136	0.8870	13	30	8 11.6 11.2 10.4 9.6
40	0.4643	25	0.5242	37	1.9074	134	0.8856	13	20	9 13.0 12.6 11.7 10.8
50	0.4669	26	0.5280	37	1.8940	132	0.8843	13	10	
28 0	0.4694	25	0.5317	37	1.8807	131	0.8829	14	0 62	
10	0.4720	25	0.5354	37	1.8676	130	0.8816	13	50	11 11 10
20	0.4746	25	0.5392	37	1.8546	128	0.8802	14	40	1 1.1 1.1 1.0
30	0.4771	25	0.5429	38	1.8417	127	0.8788	14	30	2 2.3 2.2 2.0
40	0.4797	25	0.5467	38	1.8290	125	0.8774	13	20	3 3.4 3.3 3.0
50	0.4822	25	0.5505	38	1.8165	124	0.8760	14	10	4 4.6 4.4 4.0
29 0	0.4848	25	0.5543	38	1.8040	123	0.8746	14	0 61	5 5.7 5.5 5.0
10	0.4873	25	0.5581	38	1.7917	122	0.8732	14	50	6 6.9 6.6 6.0
20	0.4899	25	0.5619	38	1.7795	121	0.8718	14	40	7 8.0 7.7 7.0
30	0.4924	25	0.5657	38	1.7675	119	0.8703	14	30	8 9.2 8.8 8.0
40	0.4949	25	0.5696	39	1.7555	118	0.8689	14	20	9 10.3 9.9 9.0
50	0.4975	25	0.5735	38	1.7437	117	0.8675	14	10	
30 0	0.5000		0.5773		1.7320		0.8660		0 60	
	Cos.	d.	Cot.	d.	Tan.	d.	Sin.	d.	° ′	P. P.

60°-70°

TABLE X.—**Natural sines, cosines, tangents, and cotangents**—*Continued.*

30°–40°

° ′	Sin.	d.	Tan.	d.	Cot.	d.	Cos.	d.		P.P.
30 0	0.5000	25	0.5773	39	1.7320	116	0.8660	15	0 60	
10	0.5025	25	0.5812	39	1.7204	114	0.8645	15	50	
20	0.5050	25	0.5851	39	1.7090	113	0.8631	14	40	49 49 48 47 46
30	0.5075	25	0.5890	39	1.6976	112	0.8616	15	30	1 4.9 4.9 4.8 4.7 4.6
40	0.5100	25	0.5929	39	1.6864	111	0.8601	15	20	2 9.9 9.8 9.6 9.4 9.2
50	0.5125	25	0.5969	39	1.6753	110	0.8586	15	10	3 14.8 14.7 14.4 14.1 13.8
31 0	0.5150	25	0.6008	39	1.6643	110	0.8571	15	0 59	4 19.8 19.6 19.2 18.8 18.4
10	0.5175	24	0.6048	40	1.6533	109	0.8556	15	50	5 24.7 24.5 24.0 23.5 23.0
20	0.5200	25	0.6088	39	1.6425	108	0.8541	15	40	6 29.7 29.4 28.8 28.2 27.6
30	0.5225	25	0.6128	40	1.6318	107	0.8526	15	30	7 34.6 34.3 33.6 32.9 32.2
40	0.5250	25	0.6168	40	1.6212	106	0.8511	15	20	8 39.6 39.2 38.4 37.6 36.8
50	0.5274	24	0.6208	40	1.6107	105	0.8496	15	10	9 44.5 44.1 43.2 42.3 41.4
32 0	0.5299	24	0.6248	40	1.6003	104	0.8480	15	0 58	45 45 44 43 42
10	0.5324	25	0.6289	40	1.5900	103	0.8465	15	50	1 4.5 4.5 4.4 4.3 4.2
20	0.5348	24	0.6330	41	1.5798	102	0.8449	15	40	2 9.1 9.0 8.8 8.6 8.4
30	0.5373	24	0.6370	40	1.5697	101	0.8434	15	30	3 13.6 13.5 13.2 12.9 12.6
40	0.5397	24	0.6411	41	1.5596	100	0.8418	16	20	4 18.2 18.0 17.6 17.2 16.8
50	0.5422	24	0.6453	41	1.5497	99	0.8402	15	10	5 22.7 22.5 22.0 21.5 21.0
33 0	0.5446	24	0.6494	41	1.5398	98	0.8386	16	0 57	6 27.3 27.0 26.4 25.8 25.2
10	0.5471	24	0.6535	42	1.5301	97	0.8371	15	50	7 31.8 31.5 30.8 30.1 29.4
20	0.5495	24	0.6577	42	1.5204	96	0.8355	16	40	8 36.4 36.0 35.2 34.4 33.6
30	0.5519	24	0.6619	42	1.5108	96	0.8339	16	30	9 40.9 40.5 39.6 38.7 37.8
40	0.5543	24	0.6661	42	1.5013	95	0.8323	16	20	41 41 40 39
50	0.5568	24	0.6703	42	1.4919	94	0.8306	16	10	1 4.1 4.1 4.0 3.9
34 0	0.5592	24	0.6745	42	1.4825	93	0.8290	16	0 56	2 8.3 8.2 8.0 7.8
10	0.5616	24	0.6787	42	1.4733	92	0.8274	16	50	3 12.4 12.3 12.0 11.7
20	0.5640	24	0.6830	42	1.4641	92	0.8257	16	40	4 16.6 16.4 16.0 15.6
30	0.5664	24	0.6873	43	1.4550	91	0.8241	16	30	5 20.7 20.5 20.0 19.5
40	0.5688	24	0.6915	42	1.4460	90	0.8225	17	20	6 24.9 24.6 24.0 23.4
50	0.5712	24	0.6959	43	1.4370	89	0.8208	16	10	7 29.0 28.7 28.0 27.3
35 0	0.5736	23	0.7002	43	1.4281	89	0.8191	16	0 55	8 33.2 32.8 32.0 31.2
10	0.5759	24	0.7045	43	1.4193	88	0.8175	16	50	9 37.3 36.9 36.0 35.1
20	0.5783	24	0.7089	44	1.4106	87	0.8158	17	40	25 25 24 23
30	0.5807	23	0.7133	44	1.4019	87	0.8141	17	30	1 2.5 2.5 2.5 2.3
40	0.5830	24	0.7177	44	1.3933	86	0.8124	17	20	2 5.1 5.0 4.8 4.6
50	0.5854	23	0.7221	44	1.3848	85	0.8107	17	10	3 7.6 7.5 7.2 6.9
36 0	0.5878	23	0.7265	44	1.3764	84	0.8090	17	0 54	4 10.2 10.0 9.6 9.2
10	0.5901	23	0.7310	44	1.3680	84	0.8073	17	50	5 12.7 12.5 12.0 11.5
20	0.5925	23	0.7354	45	1.3597	83	0.8056	17	40	6 15.3 15.0 14.4 13.8
30	0.5948	23	0.7399	45	1.3514	83	0.8038	17	30	7 17.8 17.5 16.8 16.1
40	0.5971	23	0.7444	45	1.3432	82	0.8021	17	20	8 20.4 20.0 19.2 18.4
50	0.5995	23	0.7490	45	1.3351	82	0.8004	17	10	9 22.9 22.5 21.6 20.7
37 0	0.6018	23	0.7535	45	1.3270	82	0.7986	17	0 53	22 22 18 18
10	0.6041	23	0.7581	46	1.3190	80	0.7969	17	50	1 2.2 2.2 1.8 1.8
20	0.6064	23	0.7627	46	1.3111	79	0.7951	18	40	2 4.4 4.4 3.6 3.6
30	0.6087	23	0.7673	46	1.3032	78	0.7933	17	30	3 6.7 6.6 5.4 5.4
40	0.6110	23	0.7719	46	1.2954	77	0.7916	18	20	4 9.0 8.8 7.2 7.2
50	0.6133	23	0.7766	47	1.2876	77	0.7898	18	10	5 11.2 11.0 9.0 9.0
38 0	0.6156	23	0.7813	47	1.2799	77	0.7880	18	0 52	6 13.5 13.2 11.1 10.8
10	0.6179	23	0.7860	47	1.2723	76	0.7862	18	50	7 15.7 15.4 12.6 12.6
20	0.6202	23	0.7907	47	1.2647	76	0.7844	18	40	8 18.0 17.6 14.4 14.4
30	0.6225	23	0.7954	47	1.2571	75	0.7826	18	30	9 20.2 19.8 16.2 16.2
40	0.6248	23	0.8002	48	1.2497	74	0.7808	18	20	17 17 16 15 14
50	0.6270	22	0.8050	48	1.2422	75	0.7789	18	10	1 1.7 1.7 1.6 1.5 1.4
39 0	0.6293	23	0.8098	48	1.2349	73	0.7771	18	0 51	2 3.4 3.4 3.2 3.0 2.9
10	0.6316	23	0.8146	48	1.2276	73	0.7753	18	50	3 5.2 5.1 4.8 4.5 4.3
20	0.6338	22	0.8194	49	1.2203	72	0.7734	18	40	4 7.0 6.8 6.4 6.0 5.8
30	0.6361	23	0.8243	49	1.2131	72	0.7716	18	30	5 8.7 8.5 8.0 7.5 7.2
40	0.6383	22	0.8292	49	1.2059	71	0.7697	18	20	6 10.5 10.2 9.6 9.0 8.7
50	0.6405	23	0.8341	49	1.1988	71	0.7679	18	10	7 12.2 11.9 11.2 10.5 10.1
40 0	0.6428	22	0.8391	49	1.1917	70	0.7660	18	0 50	8 14.0 13.6 12.8 12.0 11.6
	Cos.	d.	Cot.	d.	Tan.	d.	Sin.	d.	° ′	9 15.7 15.3 14.4 13.5 13.0 P.P.

50°–60°

TABLE X.—**Natural sines, cosines, tangents, and cotangents.**—*Continued.*

40°–45°

° ′	Sin.	d.	Tan.	d.	Cot.	d.	Cos.	d.	
40 0	0.6428	22	0.8391	49	1.1917	70	0.7666	19	0 50
10	0.6450	22	0.8446	50	1.1847	70	0.7641	18	50
20	0.6472	22	0.8496	50	1.1777	69	0.7623	19	40
30	0.6494	22	0.8541	50	1.1708	68	0.7604	19	30
40	0.6516	22	0.8591	51	1.1640	68	0.7585	19	20
50	0.6538	22	0.8642	51	1.1571	68	0.7566	19	10
41 0	0.6560	22	0.8693	51	1.1503	67	0.7547	19	0 49
10	0.6582	22	0.8744	51	1.1436	67	0.7528	19	50
20	0.6604	21	0.8795	52	1.1369	66	0.7509	19	40
30	0.6626	22	0.8847	51	1.1303	66	0.7489	19	30
40	0.6648	21	0.8899	52	1.1237	63	0.7470	19	20
50	0.6669	22	0.8951	52	1.1171	65	0.7451	19	10
42 0	0.6691	21	0.9004	53	1.1106	64	0.7431	19	0 48
10	0.6713	21	0.9057	53	1.1041	64	0.7412	19	50
20	0.6734	21	0.9110	53	1.0977	64	0.7392	19	40
30	0.6756	21	0.9163	53	1.0913	63	0.7373	19	30
40	0.6777	21	0.9217	54	1.0849	63	0.7353	20	20
50	0.6798	21	0.9271	54	1.0786	63	0.7333	19	10
43 0	0.6820	21	0.9325	54	1.0723	62	0.7313	20	0 47
10	0.6841	21	0.9379	55	1.0661	62	0.7293	20	50
20	0.6862	21	0.9434	55	1.0599	61	0.7273	20	40
30	0.6883	21	0.9489	55	1.0538	61	0.7253	20	30
40	0.6904	21	0.9545	56	1.0476	60	0.7233	20	20
50	0.6925	21	0.9601	56	1.0416	60	0.7213	20	10
44 0	0.6946	21	0.9657	56	1.0355	60	0.7193	20	0 46
10	0.6967	21	0.9713	56	1.0295	60	0.7173	20	50
20	0.6988	21	0.9770	57	1.0235	59	0.7153	20	40
30	0.7009	20	0.9827	57	1.0176	59	0.7132	20	30
40	0.7030	21	0.9884	57	1.0117	59	0.7112	20	20
50	0.7050	20	0.9942	58	1.0058	58	0.7091	20	10
45 0	0.7071		1.0000		1.0000		0.7071		0 45
	Cos.	d.	Cot.	d.	Tan.	d.	Sin.	d.	′ °

P. P.

	70	32	22	21	21
1	7.0	3.2	2.2	2.1	2.1
2	14.0	6.4	4.4	4.3	4.2
3	21.0	9.6	6.6	6.4	6.3
4	28.0	9.0	8.8	8.6	8.4
5	35.0	11.2	11.0	10.7	10.5
6	42.0	13.5	13.2	12.9	12.6
7	49.0	15.7	15.4	15.0	14.7
8	56.0	18.0	17.6	17.2	16.8
9	63.0	20.2	19.8	19.3	18.9

	69	26	20	19	19
1	6.9	2.6	2.0	1.9	1.9
2	13.8	5.2	4.0	3.9	3.8
3	20.7	7.8	6.0	5.8	5.7
4	27.6	8.2	8.0	7.8	7.6
5	34.5	10.8	10.0	9.7	9.5
6	41.4	12.3	12.0	11.7	11.4
7	48.3	14.3	14.0	13.6	13.3
8	55.2	16.4	16.0	15.6	15.2
9	62.1	18.4	18.0	17.5	17.1

	68	68	67	66	18
1	6.8	6.8	6.7	6.6	1.8
2	13.7	13.6	13.4	13.2	3.7
3	20.5	20.4	20.1	19.8	5.5
4	27.4	27.2	26.8	26.4	7.4
5	34.2	34.0	33.5	33.0	9.2
6	41.1	40.8	40.2	39.6	11.1
7	47.9	47.6	46.9	46.2	12.8
8	54.8	54.4	53.6	52.8	14.7
9	61.6	61.2	60.3	59.4	16.6

	65	64	64	63	62	61	60	59	59	58	58	57	57	56	56	55	54	54	53	53	52	52
1	6.5	6.4	6.4	6.3	6.2	6.1	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.4	5.4	5.3	5.3	5.2	5.2
2	13.1	12.9	12.8	12.6	12.4	12.3	12.1	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.4
3	19.6	19.3	19.2	18.9	18.6	18.4	18.1	17.8	17.7	17.5	17.4	17.2	17.1	16.9	16.8	16.5	16.3	16.2	16.0	15.9	15.7	15.6
4	26.2	25.8	25.6	25.2	24.8	24.6	24.2	23.8	23.6	23.4	23.2	23.0	22.8	22.6	22.4	22.0	21.8	21.6	21.4	21.2	21.0	20.8
5	32.7	32.2	32.0	31.5	31.0	30.7	30.2	29.7	29.5	29.2	29.0	28.7	28.5	28.2	28.0	27.5	27.2	27.0	26.7	26.5	26.2	26.0
6	39.3	38.7	38.4	37.8	37.2	36.9	36.3	35.7	35.4	35.1	34.8	34.5	34.2	33.9	33.6	33.0	32.7	32.4	32.1	31.8	31.5	31.2
7	45.8	45.1	44.8	44.1	43.4	43.0	42.3	41.6	41.3	40.9	40.6	40.2	39.9	39.5	39.2	38.5	38.1	37.8	37.4	37.1	36.7	36.4
8	52.4	51.6	51.2	50.4	49.6	49.2	48.3	47.6	47.2	46.8	46.4	46.0	45.6	45.2	44.8	44.0	43.6	43.2	42.8	42.4	42.0	41.6
9	58.9	58.0	57.6	56.7	55.8	55.3	54.4	53.5	53.2	52.6	52.2	51.7	51.3	50.8	50.4	49.5	49.1	48.6	48.2	47.7	47.3	46.8

	51	51	50	50	49
1	5.1	5.1	5.0	5.0	4.9
2	10.3	10.2	10.1	10.0	9.9
3	15.4	15.3	15.1	15.0	14.8
4	20.6	20.4	20.2	20.0	19.8
5	25.7	25.5	25.3	25.0	24.7
6	30.9	30.6	30.3	30.0	29.7
7	36.0	35.7	35.3	35.0	34.6
8	41.2	40.8	40.4	40.0	39.6
9	46.3	45.9	45.4	45.0	44.5

Table for passing from Sexagesimal to Circular Measure.

°	Circular Meas.	′	Circular Meas.	″	Circular Meas.
100	1.74 532 9	10	0.00 290 9	10	0.00 004 8
200	3.49 065 8	20	0.00 581 8	20	0.00 009 7
300	5.23 598 8	30	0.00 872 6	30	0.00 014 5
		40	0.01 163 5	40	0.00 019 4
40	0.69 813 1				
50	0.87 266 4	50	0.01 454 2	50	0.00 024 2
60	1.04 719 7				
		6	0.00 174 5	6	0.00 002 9
70	1.22 173 0	7	0.00 203 6	7	0.00 003 4
80	1.39 626 3	8	0.00 232 7	8	0.00 003 9
90	1.57 079 6	9	0.00 261 8	9	0.00 004 3

TABLE XI.—Natural versed sines and external secants.

0°–10

° ′	Vers.	d.	Exsec.	d.
0 0	.00000		.00000	
10	.00000	0	.00000	0
20	.00001	1	.00001	1
30	.00004	2	.00004	2
40	.00007	3	.00007	3
50	.00010	3	.00010	3
1 0	.00015	5	.00015	5
10	.00020	5	.00020	5
20	.00027	7	.00027	7
30	.00034	7	.00034	7
40	.00042	8	.00042	8
50	.00051	9	.00051	9
2 0	.00061	10	.00061	10
10	.00071	11	.00071	11
20	.00083	12	.00083	12
30	.00095	12	.00095	12
40	.00108	13	.00108	13
50	.00122	14	.00122	14
3 0	.00137	15	.00137	15
10	.00152	15	.00153	15
20	.00169	17	.00169	17
30	.00186	17	.00187	18
40	.00204	18	.00205	18
50	.00223	19	.00224	19
4 0	.00243	20	.00244	20
10	.00264	21	.00265	21
20	.00286	22	.00286	22
30	.00308	22	.00309	23
40	.00331	23	.00332	23
50	.00355	24	.00357	25
5 0	.00380	25	.00382	25
10	.00406	26	.00408	26
20	.00433	27	.00435	27
30	.00460	27	.00462	27
40	.00488	28	.00491	29
50	.00518	30	.00520	29
6 0	.00548	30	.00551	31
10	.00578	32	.00582	32
20	.00610	32	.00614	33
30	.00643	33	.00647	33
40	.00676	33	.00681	34
50	.00710	35	.00715	35
7 0	.00745	36	.00751	36
10	.00781	36	.00787	37
20	.00818	37	.00824	38
30	.00855	38	.00863	39
40	.00894	39	.00902	40
50	.00933	40	.00942	41
8 0	.00973	41	.00983	41
10	.01014	41	.01024	42
20	.01056	42	.01067	43
30	.01098	42	.01110	43
40	.01142	44	.01155	45
50	.01186	45	.01200	46
9 0	.01231	46	.01246	47
10	.01277	47	.01293	48
20	.01324	47	.01341	49
30	.01371	48	.01390	50
40	.01420	49	.01440	50
50	.01469	50	.01491	51
10 0	.01519	50	.01542	51
° ′	Vers.	d.	Exsec.	d.

10°–20°

° ′	Vers.	d.	Exsec.	d.
10 0	.01519	51	.01542	52
10	.01570	52	.01595	53
20	.01622	52	.01648	54
30	.01674	53	.01703	55
40	.01728	54	.01758	56
50	.01782	55	.01814	57
11 0	.01837	55	.01871	58
10	.01893	57	.01929	59
20	.01950	57	.01988	60
30	.02007	58	.02048	61
40	.02066	59	.02109	62
50	.02125	60	.02171	62
12 0	.02185	61	.02234	63
10	.02246	62	.02297	65
20	.02308	62	.02362	65
30	.02370	63	.02428	66
40	.02434	64	.02494	67
50	.02498	65	.02562	68
13 0	.02563	66	.02630	69
10	.02629	66	.02700	70
20	.02695	67	.02770	71
30	.02763	68	.02841	72
40	.02831	69	.02914	73
50	.02900	70	.02987	74
14 0	.02970	70	.03061	75
10	.03041	72	.03136	75
20	.03113	72	.03213	77
30	.03185	72	.03290	77
40	.03258	74	.03369	79
50	.03332	75	.03447	80
15 0	.03407	75	.03527	81
10	.03483	76	.03609	82
20	.03559	77	.03691	82
30	.03637	78	.03774	84
40	.03715	79	.03858	85
50	.03794	80	.03943	86
16 0	.03874	80	.04030	87
10	.03954	81	.04117	88
20	.04036	82	.04205	89
30	.04118	83	.04295	90
40	.04201	84	.04385	91
50	.04285	84	.04476	92
17 0	.04369	85	.04569	93
10	.04455	86	.04662	95
20	.04541	87	.04757	95
30	.04628	87	.04853	96
40	.04716	89	.04949	98
50	.04805	89	.05047	98
18 0	.04894	90	.05146	100
10	.04984	91	.05246	101
20	.05075	92	.05347	102
30	.05167	92	.05449	103
40	.05260	93	.05552	104
50	.05354	94	.05656	105
19 0	.05448	95	.05762	106
10	.05543	98	.05868	107
20	.05639	97	.05976	109
30	.05736	97	.06085	109
40	.05833	98	.06194	111
50	.05931	99	.06305	112
20 0	.06030		.06418	
° ′	Vers.	d.	Exsec.	d.

P. P.

	110	100	90	80	70
1	11	10	9	8	7
2	22	20	18	16	14
3	33	30	27	24	21
4	44	40	36	32	28
5	55	50	45	40	35
6	66	60	54	48	42
7	77	70	63	56	49
8	88	80	72	64	56
9	99	90	81	72	63

	60	50	40	30	20
1	6	5	4	3	2
2	12	10	8	6	4
3	18	15	12	9	6
4	24	20	16	12	8
5	30	25	20	15	10
6	36	30	24	18	12
7	42	35	28	21	14
8	48	40	32	24	16
9	54	45	36	27	18

	10	9	8	8	8
1	1	0.9	0.9	0.8	0.8
2	2	1.8	1.8	1.7	1.6
3	3	2.8	2.7	2.5	2.4
4	4	3.8	3.6	3.4	3.2
5	5	4.7	4.5	4.2	4.0
6	6	5.7	5.4	5.1	4.8
7	7	6.6	6.3	5.9	5.6
8	8	7.6	7.2	6.8	6.4
9	9	8.5	8.1	7.6	7.2

	7	7	6	6	5
1	0.7	0.7	0.6	0.6	0.5
2	1.5	1.4	1.3	1.2	1.1
3	2.2	2.1	1.9	1.8	1.6
4	3.0	2.8	2.6	2.4	2.2
5	3.7	3.5	3.2	3.0	2.7
6	4.5	4.2	3.9	3.6	3.3
7	5.2	4.9	4.5	4.2	3.8
8	6.0	5.6	5.2	4.8	4.4
9	6.7	6.3	5.8	5.4	4.9

	5	4	4	3	3
1	0.5	0.4	0.4	0.3	0.3
2	1.0	0.9	0.8	0.7	0.6
3	1.5	1.3	1.2	1.0	0.9
4	2.0	1.8	1.6	1.4	1.2
5	2.5	2.2	2.0	1.7	1.5
6	3.0	2.7	2.4	2.1	1.8
7	3.5	3.1	2.8	2.4	2.1
8	4.0	3.6	3.2	2.8	2.4
9	4.5	4.0	3.6	3.1	2.7

	2	2	1	1	0
1	0.2	0.2	0.1	0.1	0.0
2	0.5	0.4	0.3	0.2	0.1
3	0.7	0.6	0.4	0.3	0.1
4	1.0	0.8	0.6	0.4	0.2
5	1.2	1.0	0.7	0.5	0.2
6	1.5	1.2	0.9	0.6	0.3
7	1.7	1.4	1.0	0.7	0.3
8	2.0	1.6	1.2	0.8	0.4
9	2.2	1.8	1.3	0.9	0.4

P. P.

TABLE XI.—Natural versed sines and external secants—*Continued.*

20°–30°

° ′	Vers.	d.	Exsec.	d.
20 0	.0603	10	.0642	11
10	.0613	10	.0653	11
20	.0623	10	.0664	11
30	.0633	10	.0676	12
40	.0643	10	.0688	11
50	.0654	10	.0699	12
21 0	.0664	10	.0711	12
10	.0674	10	.0723	12
20	.0685	10	.0735	12
30	.0696	11	.0748	12
40	.0706	10	.0760	12
50	.0717	11	.0772	13
22 0	.0728	10	.0785	12
10	.0739	11	.0798	13
20	.0750	11	.0811	13
30	.0761	11	.0824	13
40	.0772	11	.0837	13
50	.0783	11	.0850	13
23 0	.0795	11	.0863	13
10	.0806	11	.0877	13
20	.0818	11	.0890	14
30	.0829	11	.0904	14
40	.0841	11	.0918	14
50	.0853	12	.0932	14
24 0	.0864	12	.0946	14
10	.0876	12	.0960	14
20	.0888	12	.0975	14
30	.0900	12	.0989	14
40	.0912	12	.1004	15
50	.0924	12	.1019	15
25 0	.0937	12	.1034	15
10	.0949	12	.1049	15
20	.0961	12	.1064	15
30	.0974	12	.1079	15
40	.0986	12	.1094	16
50	.0999	13	.1110	15
26 0	.1012	13	.1126	16
10	.1025	13	.1142	16
20	.1037	13	.1158	16
30	.1050	13	.1174	16
40	.1063	13	.1190	16
50	.1077	13	.1206	17
27 0	.1090	13	.1223	16
10	.1103	13	.1240	17
20	.1116	13	.1257	17
30	.1130	13	.1274	17
40	.1143	13	.1291	17
50	.1157	13	.1308	17
28 0	.1170	13	.1325	18
10	.1184	14	.1343	17
20	.1198	14	.1361	18
30	.1212	13	.1379	18
40	.1225	14	.1397	18
50	.1239	14	.1415	18
29 0	.1254	14	.1433	18
10	.1268	14	.1452	18
20	.1282	14	.1470	19
30	.1296	14	.1489	19
40	.1311	14	.1508	19
50	.1325	14	.1527	19
30 0	.1339		.1547	
° ′	Vers.	d.	Exsec.	d.

30°–40°

° ′	Vers.	d.	Exsec.	d.
30 0	.1339	15	.1547	19
10	.1354	14	.1566	19
20	.1369	14	.1586	20
30	.1383	15	.1606	20
40	.1398	15	.1626	20
50	.1413	15	.1646	20
31 0	.1428	15	.1666	20
10	.1443	15	.1687	20
20	.1458	15	.1707	21
30	.1473	15	.1728	21
40	.1489	15	.1749	21
50	.1504	15	.1770	21
32 0	.1519	15	.1792	22
10	.1535	15	.1813	21
20	.1550	15	.1835	22
30	.1566	16	.1857	22
40	.1582	15	.1879	22
50	.1597	16	.1901	22
33 0	.1613	15	.1923	23
10	.1629	16	.1946	22
20	.1645	16	.1969	23
30	.1661	16	.1992	23
40	.1677	16	.2015	23
50	.1693	16	.2038	23
34 0	.1709	16	.2062	24
10	.1726	16	.2086	24
20	.1742	16	.2110	24
30	.1758	16	.2134	24
40	.1775	17	.2158	24
50	.1792	16	.2183	24
35 0	.1808	16	.2207	25
10	.1825	17	.2232	25
20	.1842	17	.2258	25
30	.1859	17	.2283	25
40	.1876	17	.2309	25
50	.1893	17	.2334	26
36 0	.1910	17	.2360	26
10	.1927	17	.2387	26
20	.1944	17	.2413	26
30	.1961	17	.2440	27
40	.1979	17	.2467	27
50	.1996	17	.2494	27
37 0	.2013	17	.2521	27
10	.2031	18	.2549	28
20	.2049	17	.2576	28
30	.2066	17	.2604	28
40	.2084	18	.2633	28
50	.2102	18	.2661	28
38 0	.2120	18	.2690	29
10	.2138	18	.2719	29
20	.2156	18	.2748	29
30	.2174	18	.2778	29
40	.2192	18	.2807	30
50	.2210	18	.2837	30
39 0	.2228	18	.2867	30
10	.2247	18	.2898	30
20	.2265	18	.2928	31
30	.2284	18	.2959	31
40	.2303	18	.2991	31
50	.2321	18	.3022	31
40 0	.2340		.3054	
° ′	Vers.	d.	Exsec.	d.

P. P. °

	31	30	29	28
1	3.1	3.0	2.9	2.8
2	6.2	6.0	5.8	5.6
3	9.3	9.0	8.7	8.4
4	12.4	12.0	11.6	11.2
5	15.5	15.0	14.5	14.0
6	18.6	18.0	17.4	16.8
7	21.7	21.0	20.3	19.6
8	24.8	24.0	23.2	22.4
9	27.9	27.0	26.1	25.2

	27	26	25	24
1	2.7	2.6	2.5	2.4
2	5.4	5.2	5.0	4.8
3	8.1	7.8	7.5	7.2
4	10.8	10.4	10.0	9.6
5	13.5	13.0	12.5	12.0
6	16.2	15.6	15.0	14.4
7	18.9	18.2	17.5	16.8
8	21.6	20.8	20.0	19.2
9	24.3	23.4	22.5	21.6

	23	22	21	20
1	2.3	2.2	2.1	2.0
2	4.6	4.4	4.2	4.0
3	6.9	6.6	6.3	6.0
4	9.2	8.8	8.4	8.0
5	11.5	11.0	10.5	10.0
6	13.8	13.2	12.6	12.0
7	16.1	15.4	14.7	14.0
8	18.4	17.6	16.8	16.0
9	20.7	19.8	18.9	18.0

	19	18	17	16
1	1.9	1.8	1.7	1.6
2	3.8	3.6	3.4	3.2
3	5.7	5.4	5.1	4.8
4	7.6	7.2	6.8	6.4
5	9.5	9.0	8.5	8.0
6	11.4	10.8	10.2	9.6
7	13.3	12.6	11.9	11.2
8	15.2	14.4	13.6	12.8
9	17.1	16.2	15.3	14.4

	15	14	13	12
1	1.5	1.4	1.3	1.2
2	3.0	2.8	2.6	2.4
3	4.5	4.2	3.9	3.6
4	6.0	5.6	5.2	4.8
5	7.5	7.0	6.5	6.0
6	9.0	8.4	7.8	7.2
7	10.5	9.8	9.1	8.4
8	12.0	11.2	10.4	9.6
9	13.5	12.6	11.7	10.8

	11	10	9
1	1.1	1.0	0.9
2	2.2	2.0	1.8
3	3.3	3.0	2.7
4	4.4	4.0	3.6
5	5.5	5.0	4.5
6	6.6	6.0	5.4
7	7.7	7.0	6.3
8	8.8	8.0	7.2
9	9.9	9.0	8.1

P. P.

TABLE XI.—**Natural versed sines and external secants**—*Continued.*

40°–50°

° ′	Vers.	d.	Exsec.	d.
40 0	.2339	19	.3054	32
10	.2358	19	.3086	32
20	.2377	19	.3118	32
30	.2396	19	.3151	32
40	.2415	19	.3183	33
50	.2434	19	.3217	33
41 0	.2453	19	.3250	34
10	.2472	19	.3284	33
20	.2491	19	.3317	34
30	.2510	19	.3352	34
40	.2529	19	.3386	34
50	.2549	19	.3421	35
42 0	.2568	19	.3456	35
10	.2588	19	.3491	36
20	.2607	19	.3527	36
30	.2627	20	.3563	36
40	.2647	19	.3599	37
50	.2666	20	.3636	37
43 0	.2686	20	.3673	37
10	.2706	20	.3710	37
20	.2726	20	.3748	38
30	.2746	20	.3786	38
40	.2766	20	.3824	39
50	.2786	20	.3863	38
44 0	.2806	20	.3901	39
10	.2827	20	.3941	39
20	.2847	20	.3980	40
30	.2867	20	.4020	40
40	.2888	20	.4060	40
50	.2908	20	.4101	41
45 0	.2929	20	.4142	41
10	.2949	20	.4183	41
20	.2970	21	.4225	42
30	.2991	20	.4267	42
40	.3011	21	.4309	43
50	.3032	21	.4352	43
46 0	.3053	21	.4395	43
10	.3074	21	.4439	44
20	.3095	21	.4483	44
30	.3116	21	.4527	44
40	.3137	21	.4572	45
50	.3159	21	.4617	45
47 0	.3180	21	.4663	45
10	.3201	21	.4708	46
20	.3222	21	.4755	46
30	.3244	21	.4802	47
40	.3265	21	.4849	47
50	.3287	21	.4896	48
48 0	.3308	22	.4945	48
10	.3330	21	.4993	48
20	.3352	22	.5042	48
30	.3374	21	.5091	50
40	.3395	22	.5141	50
50	.3417	22	.5192	50
49 0	.3439	22	.5242	51
10	.3461	22	.5294	51
20	.3483	22	.5345	52
30	.3505	22	.5397	53
40	.3527	22	.5450	53
50	.3550	22	.5503	53
50 0	.3572		.5557	
° ′	Vers.	d.	Exsec.	d.

50°–60°

° ′	Vers.	d.	Exsec.	d.
50 0	.3572	22	.5557	53
10	.3594	22	.5611	54
20	.3617	22	.5666	54
30	.3639	22	.5721	55
40	.3661	22	.5777	56
50	.3684	23	.5833	56
51 0	.3707	22	.5890	57
10	.3729	22	.5947	58
20	.3752	23	.6005	58
30	.3775	22	.6064	59
40	.3797	23	.6123	59
50	.3820	23	.6182	60
52 0	.3843	23	.6242	61
10	.3866	23	.6303	61
20	.3889	23	.6365	62
30	.3912	23	.6427	62
40	.3935	23	.6489	63
50	.3958	23	.6552	64
53 0	.3982	23	.6616	64
10	.4005	23	.6681	65
20	.4028	23	.6746	65
30	.4052	23	.6811	66
40	.4075	23	.6878	67
50	.4098	23	.6945	68
54 0	.4122	23	.7013	68
10	.4145	24	.7081	69
20	.4169	23	.7150	70
30	.4193	23	.7220	70
40	.4216	24	.7291	71
50	.4240	23	.7362	72
55 0	.4264	24	.7434	73
10	.4288	24	.7507	73
20	.4312	24	.7581	74
30	.4336	24	.7655	75
40	.4360	24	.7730	75
50	.4384	24	.7806	77
56 0	.4408	24	.7883	77
10	.4432	24	.7960	78
20	.4456	24	.8039	79
30	.4480	24	.8118	80
40	.4505	24	.8198	81
50	.4529	24	.8279	82
57 0	.4553	24	.8361	83
10	.4578	24	.8443	83
20	.4602	24	.8527	84
30	.4627	24	.8611	85
40	.4651	24	.8697	86
50	.4676	25	.8783	87
58 0	.4701	24	.8871	88
10	.4725	24	.8959	89
20	.4750	25	.9048	90
30	.4775	25	.9139	91
40	.4800	24	.9230	92
50	.4824	25	.9322	93
59 0	.4849	25	.9416	94
10	.4874	25	.9510	95
20	.4899	25	.9606	97
30	.4924	25	.9703	98
40	.4949	25	.9801	99
50	.4975	25	.9900	100
60 0	.5000		1.0000	
° ′	Vers.	d.	Exsec.	d.

d.	P. P.					
	9	8	7	6	5	4
53	1 0.9	0.8	0.7	0.6	0.5	0.4
54	2 1.8	1.6	1.4	1.2	1.0	0.8
54	3 2.7	2.4	2.1	1.8	1.5	1.2
55	4 3.6	3.2	2.8	2.4	2.0	1.6
56	5 4.5	4.0	3.5	3.0	2.5	2.0
56	6 5.4	4.8	4.2	3.6	3.0	2.4
57	7 6.3	5.6	4.9	4.2	3.5	2.8
58	8 7.2	6.4	5.6	4.8	4.0	3.2
58	9 8.1	7.2	6.3	5.4	4.5	3.6
59						
59	3	2	1	0	8	7
60	1 0.3	0.2	0.1	0.0	0.8	0.7
61	2 0.6	0.4	0.2	0.1	1.7	1.5
61	3 0.9	0.6	0.3	2.8	2.5	2.2
62	4 1.2	0.8	0.4	3.8	3.4	3.0
62	5 1.5	1.0	0.5	4.7	4.2	3.7
63	6 1.8	1.2	0.6	5.7	5.1	4.5
64	7 2.1	1.4	0.7	6.6	5.9	5.2
64	8 2.4	1.6	0.8	7.6	6.8	6.0
65	9 2.7	1.8	0.9	8.5	7.6	6.7
65						
65	6	5	4	3	2	1
66	1 0.6	0.5	0.4	0.3	0.2	0.1
67	2 1.3	1.1	0.9	0.7	0.5	0.3
68	3 1.9	1.6	1.3	1.0	0.7	0.4
68	4 2.6	2.2	1.8	1.4	1.0	0.6
69	5 3.2	2.7	2.2	1.7	1.2	0.7
70	6 3.9	3.3	2.7	2.1	1.5	0.9
70	7 4.5	3.8	3.1	2.4	1.7	1.0
71	8 5.2	4.4	3.6	2.8	2.0	1.2
72	9 5.8	4.9	4.0	3.1	2.2	1.3
73						
73	2½	25	2¼	24	2¾	
74	1 2.5	2.5	2.4	2.4	2.3	
75	2 5.1	5.0	4.9	4.8	4.7	
75	3 7.6	7.5	7.3	7.2	7.0	
76	4 10.2	10.0	9.8	9.6	9.4	
77	5 12.7	12.5	12.2	12.0	11.7	
77	6 15.3	15.0	14.7	14.4	14.1	
78	7 17.8	17.5	17.1	16.8	16.4	
79	8 20.4	20.0	19.6	19.2	18.8	
80	9 22.9	22.5	22.0	21.6	21.1	
81						
82	23	22	22	21	21	
83	1 2.3	2.2	2.2	2.1	2.1	
83	2 4.6	4.5	4.4	4.3	4.2	
84	3 6.9	6.7	6.6	6.4	6.3	
85	4 9.2	9.0	8.8	8.6	8.4	
86	5 11.5	11.2	11.0	10.7	10.5	
87	6 13.8	13.5	13.2	12.9	12.6	
88	7 16.1	15.7	15.4	15.0	14.7	
89	8 18.4	18.0	17.6	17.2	16.8	
90	9 20.7	20.2	19.8	19.3	18.9	
91						
92	20	20	19	19	18	
93	1 2.0	2.0	1.9	1.9	1.8	
94	2 4.1	4.0	3.9	3.8	3.7	
95	3 6.1	6.0	5.8	5.7	5.5	
97	4 8.2	8.0	7.8	7.6	7.4	
98	5 10.2	10.0	9.7	9.5	9.2	
99	6 12.3	12.0	11.7	11.4	11.1	
100	7 14.3	14.0	13.6	13.3	12.9	
	8 16.4	16.0	15.6	15.2	14.8	
	9 18.4	18.0	17.5	17.1	16.6	
	P. P.					

TABLE XI.—Natural versed sines and external secants—*Continued.*

80°–70°						70°–80°					
° ′	Vers.	d.	Exsec.	d.	° ′	Vers.	d.	Exsec.	d.	P. P.
60 0	.5000	25	1·0000	101	70 0	.6580	27	1·9238	235	9 8 7 6 5
10	.5025	25	1·0101	102	10	.6607	27	1·9473	240	1·0 9·0 8·0 7·0 6·0 5·0
20	.5050	25	1·0204	103	20	.6634	27	1·9713	244	2·1 8·1 7·1 6·1 5·1 4·1
30	.5076	25	1·0307	105	30	.6662	27	1·9957	248	3·2 7·2 6·2 5·2 4·2 3·2
40	.5101	25	1·0413	106	40	.6689	27	2·0205	253	4·3 6·3 5·3 4·3 3·3 2·3
50	.5126	25	1·0519	107	50	.6717	27	2·0458	257	5·4 5·4 4·4 3·4 2·4 1·4
61 0	.5152	25	1·0626	109	71 0	.6744	27	2·0715	262	6·5 4·5 3·5 2·5 1·5 0·5
10	.5177	25	1·0735	110	10	.6772	27	2·0977	266	7·6 3·6 2·6 1·6 0·6 9·4
20	.5203	25	1·0846	111	20	.6799	27	2·1244	271	8·7 2·6 1·6 0·6 9·5 8·4
30	.5228	25	1·0957	113	30	.6827	27	2·1515	276	9·8 1·7 0·7 9·6 8·5 7·4
40	.5254	25	1·1070	114	40	.6854	27	2·1792	281	4 3 2 1 0
50	.5279	26	1·1184	116	50	.6882	27	2·2073	287	1·0 4·0 3·0 2·0 1·0 0·5
62 0	.5305	25	1·1300	117	72 0	.6910	28	2·2360	292	2·0 8·0 6·0 4·0 2·0 1·9
10	.5331	25	1·1418	118	10	.6937	27	2·2653	298	3·1 2·0 9·0 6·0 3·0 2·8
20	.5356	26	1·1536	120	20	.6965	28	2·2951	304	4·1 6·1 2·0 8·0 4·0 3·8
30	.5382	26	1·1657	121	30	.6993	28	2·3255	310	5·2 0·1 5·1 0·0 0·5 4·7
40	.5408	25	1·1778	123	40	.7020	28	2·3565	316	6·2 4·1 8·1 2·0 6·5 5·7
50	.5434	26	1·1902	125	50	.7048	28	2·3881	322	7·2 8·1 1·1 4·0 7·6 6·6
63 0	.5460	26	1·2027	126	73 0	.7076	27	2·4203	328	8·3 2·2 4·1 6·0 8·7 7·6
10	.5486	26	1·2153	128	10	.7104	28	2·4531	335	9·3 6·2 7·1 8·0 9·8 8·5
20	.5512	26	1·2281	130	20	.7132	28	2·4867	342	8 7 6 5 4
30	.5538	26	1·2411	131	30	.7160	27	2·5209	349	1·0 8·0 7·0 6·0 5·0 4·0
40	.5564	26	1·2543	133	40	.7187	28	2·5558	356	2·1 7·1 5·1 3·1 1·0 9·0
50	.5590	26	1·2676	135	50	.7215	28	2·5915	364	3·2 5·2 2·1 9·1 6·1 3·1
64 0	.5616	26	1·2811	137	74 0	.7243	28	2·6279	372	4·3 4·3 0·2 6·2 2·1 8·2
10	.5642	26	1·2948	139	10	.7271	28	2·6651	380	5·4 2·3 7·3 2·2 7·2 2·2
20	.5668	26	1·3087	140	20	.7299	28	2·7031	389	6·5 1·4 5·3 9·3 3·2 7·2
30	.5695	26	1·3228	143	30	.7327	28	2·7420	396	7·5 9·5 2·4 5·3 8·3 1·2
40	.5721	26	1·3371	144	40	.7355	28	2·7816	406	8·6 8·6 0·5 2·4 4·3 6·2
50	.5747	26	1·3515	146	50	.7383	28	2·8222	414	9·7 6·6 7·5 8·4 9·4 0·3
65 0	.5774	26	1·3662	148	75 0	.7412	28	2·8637	424	3 2 1
10	.5800	26	1·3810	151	10	.7440	28	2·9061	434	1·0 3·0 2·0 1·0
20	.5826	26	1·3961	152	20	.7468	28	2·9495	444	2·0 7·0 5·0 3·0
30	.5853	26	1·4114	155	30	.7496	28	2·9939	454	3·1 0·0 7·0 4·0
40	.5879	26	1·4269	157	40	.7524	28	3·0394	465	4·1 4·1 0·0 6·0
50	.5906	26	1·4426	159	50	.7552	28	3·0859	476	5·1 7·1 2·0 7·0
66 0	.5932	26	1·4586	161	76 0	.7581	28	3·1335	488	6·2 1·1 5·0 9·0
10	.5959	27	1·4747	164	10	.7609	28	3·1824	500	7·2 4·1 7·1 1·0
20	.5986	26	1·4912	166	20	.7637	28	3·2324	512	8·2 8·2 0·1 2·0
30	.6012	26	1·5078	169	30	.7665	28	3·2836	525	9·3 1·2 2·1 3·0
40	.6039	27	1·5247	171	40	.7694	28	3·3362	539	29 28 28 27
50	.6066	26	1·5419	174	50	.7722	28	3·3901	553	1 2·9 2·8 2·8 2·7
67 0	.6092	27	1·5593	177	77 0	.7750	28	3·4454	567	2 5·8 5·7 5·6 5·5
10	.6119	27	1·5770	179	10	.7779	28	3·5021	582	3 8·7 8·5 8·4 8·2
20	.6146	26	1·5949	182	20	.7807	28	3·5604	598	4 11·6 11·4 11·2 11·0
30	.6173	27	1·6131	184	30	.7835	28	3·6202	614	5 14·5 14·2 14·0 13·7
40	.6200	27	1·6316	188	40	.7864	28	3·6816	631	6 17·4 17·1 16·8 16·5
50	.6227	27	1·6504	190	50	.7892	28	3·7448	649	7 20·3 19·9 19·6 19·2
68 0	.6254	27	1·6694	194	78 0	.7921	28	3·8097	667	8 23·2 22·8 22·4 22·0
10	.6281	27	1·6888	196	10	.7949	28	3·8765	686	9 26·1 25·6 25·2 24·7
20	.6308	27	1·7085	200	20	.7978	28	3·9451	707	27 26 26 25
30	.6335	27	1·7285	203	30	.8006	28	4·0158	728	1 2·7 2·6 2·6 2·5
40	.6362	27	1·7488	206	40	.8035	28	4·0886	748	2 5·4 5·3 5·2 5·1
50	.6389	27	1·7694	210	50	.8063	28	4·1636	773	3 8·1 7·9 7·8 7·6
69 0	.6416	27	1·7904	213	79 0	.8092	27	4·2408	796	4 10·8 10·6 10·4 10·2
10	.6443	27	1·8117	218	10	.8120	28	4·3205	821	5 13·5 13·2 13·0 12·7
20	.6470	27	1·8334	220	20	.8149	28	4·4026	847	6 16·2 15·9 15·6 15·3
30	.6498	27	1·8554	224	30	.8177	29	4·4874	875	7 18·9 18·5 18·2 17·8
40	.6525	27	1·8778	228	40	.8206	28	4·5749	904	8 21·6 21·2 20·8 20·4
50	.6552	27	1·9006	231	50	.8235	28	4·6653	934	9 24·3 23·8 23·4 22·9
70 0	.6580		1·9238		80 0	.8263		4·7587		P. P.
° ′	Vers.	d.	Exsec.	d.	° ′	Vers.	d.	Exsec.	d.	

TABLE XI.—Natural versed sines and external secants—*Continued.*

80°–85°

° ′	Vers.	d.	Exsec.	d.
80 0	.8263	28	4.7587	966
10	.8292	29	4.8554	999
20	.8321	28	4.9553	1035
30	.8349	28	5.0588	1072
40	.8378	29	5.1660	1111
50	.8407	28	5.2772	1152
81 0	.8435	29	5.3924	1195
10	.8464	28	5.5121	1242
20	.8493	28	5.6363	1291
30	.8522	28	5.7654	1343
40	.8550	29	5.8998	1398
50	.8579	29	6.0396	1456
82 0	.8608	28	6.1853	1519
10	.8637	29	6.3372	1585
20	.8666	28	6.4957	1656
30	.8694	29	6.6613	1731
40	.8723	29	6.8344	1812
50	.8752	29	7.0156	1898
83 0	.8781	28	7.2055	1997
10	.8810	29	7.4046	2091
20	.8839	29	7.6138	2198
30	.8868	29	7.8336	2315
40	.8897	29	8.0651	2440
50	.8926	28	8.3091	2576
84 0	.8954	29	8.5667	2723
10	.8983	29	8.8391	2884
20	.9012	28	9.1275	3053
30	.9041	29	9.4334	3250
40	.9070	29	9.7585	3460
50	.9099		10.1045	3691
85 0	.9128	29	10.4737	
° ′	Vers.	d.	Exsec.	d.

85°–90°

° ′	Vers.	d.	Exsec.	d.
85 0	.9128	29	10.4737	.3946
10	.9157	29	10.8683	.4229
20	.9186	29	11.2912	.4542
30	.9215	29	11.7455	.4892
40	.9244	29	12.2347	.5284
50	.9273	29	12.7631	.5725
86 0	.9302	29	13.3356	.6223
10	.9331	29	13.9579	.6789
20	.9360	29	14.6368	.7436
30	.9389	29	15.3804	.8180
40	.9418	29	16.1984	.9041
50	.9447	29	17.1026	1.0047
87 0	.9476	29	18.1073	1.1230
10	.9505	29	19.2303	1.2634
20	.9534	29	20.4937	1.4319
30	.9564	29	21.9256	1.6365
40	.9593	29	23.5621	1.8884
50	.9622	29	25.4505	2.2082
88 0	.9651	29	27.6537	2.6039
10	.9680	29	30.2576	3.1247
20	.9709	29	33.3823	3.8192
30	.9738	29	37.2015	4.7741
40	.9767	29	41.9757	6.1383
50	.9796	29	48.1140	8.1846
89 0	.9825	29	56.2987	
10	.9854	29	67.7573	
20	.9883	29	84.9456	
30	.9912	29	113.5930	
40	.9942	29	170.8883	
50	.9971	29	342.7752	
90 0	1.0000		∞	
° ′	Vers.	d.	Exsec.	d.

	P. P.	
	29	29
1	2.9	2.9
2	5.8	5.8
3	8.7	8.7
4	11.6	11.6
5	14.5	14.5
6	17.4	17.4
7	20.3	20.3
8	23.2	23.2
9	26.1	26.1
		28
1	2.8	
2	5.7	
3	8.5	
4	11.4	
5	14.2	
6	17.1	
7	19.9	
8	22.8	
9	25.6	

TABLE XII.—**Elements of a circular curve** of 1° curvature, 5,730 ft. radius.

Δ	Tang., T.	Ext. dist., E.	Long chord, L. C.	Δ	Tang., T.	Ext. dist., E.	Long chord, L. C.
° ′				° ′			
1 00	50.00	0.218	100.00	9 00	450.93	17.717	899.09
10	58.34	0.297	116.67	10	459.32	18.381	915.70
20	66.67	0.388	133.33	20	467.71	19.058	932.31
30	75.01	0.491	150.00	30	476.10	19.746	948.92
40	83.34	0.606	166.66	40	484.49	20.447	965.53
50	91.68	0.733	183.33	50	492.88	21.161	982.14
2 00	100.01	0.873	199.99	10 00	501.28	21.886	998.74
10	108.35	1.024	216.66	10	509.68	22.624	1015.35
20	116.68	1.188	233.32	20	518.08	23.375	1031.95
30	125.02	1.364	249.98	30	526.48	24.138	1048.54
40	133.36	1.552	266.65	40	534.89	24.913	1065.14
50	141.70	1.752	283.31	50	543.29	25.700	1081.73
3 00	150.04	1.964	299.97	11 00	551.70	26.500	1098.3
10	158.38	2.188	316.63	10	560.11	27.313	1114.9
20	166.72	2.425	333.29	20	568.53	28.137	1131.5
30	175.06	2.674	349.95	30	576.95	28.974	1148.1
40	183.40	2.934	366.61	40	585.36	29.824	1164.7
50	191.74	3.207	383.27	50	593.79	30.686	1181.2
4 00	200.08	3.492	399.92	12 00	602.21	31.561	1197.8
10	208.43	3.790	416.58	10	610.64	32.447	1214.4
20	216.77	4.099	433.24	20	619.07	33.347	1231.0
30	225.12	4.421	449.89	30	627.50	34.259	1247.5
40	233.47	4.755	466.54	40	635.93	35.183	1264.1
50	241.81	5.100	483.20	50	644.37	36.120	1280.7
5 00	250.16	5.459	499.85	13 00	652.81	37.069	1297.2
10	258.51	5.829	516.50	10	661.25	38.031	1313.8
20	266.86	6.211	583.15	20	669.70	39.006	1330.3
30	275.21	6.606	549.80	30	678.15	39.993	1346.9
40	283.57	7.013	566.44	40	686.60	40.992	1363.4
50	291.92	7.432	583.09	50	695.06	42.004	1380.0
6 00	300.28	7.863	599.73	14 00	703.51	43.029	1396.5
10	308.64	8.307	616.38	10	711.97	44.066	1413.1
20	316.99	8.762	633.02	20	720.44	45.116	1429.6
30	325.35	9.230	649.66	30	728.90	46.178	1446.2
40	333.71	9.710	666.30	40	737.37	47.253	1462.7
50	342.08	10.202	682.94	50	745.85	48.341	1479.2
7 00	350.44	10.707	699.57	15 00	754.32	49.441	1495.7
10	358.81	11.224	716.21	10	762.80	50.554	1512.3
20	367.17	11.753	732.84	20	771.29	51.679	1528.8
30	375.54	12.294	749.47	30	779.77	52.818	1545.3
40	383.91	12.847	766.10	40	788.26	53.969	1561.8
50	392.28	13.413	782.73	50	796.75	55.132	1578.3
8 00	400.66	13.991	799.36	16 00	805.25	56.309	1594.8
10	409.03	14.582	815.99	10	813.75	57.498	1611.3
20	417.41	15.184	832.61	20	822.25	58.699	1627.8
30	425.79	15.799	849.23	30	830.76	59.914	1644.3
40	434.17	16.426	865.85	40	839.27	61.141	1660.8
50	442.55	17.066	882.47	50	847.78	62.381	1677.3

TABLE XII.—Elements of a circular curve of 1° curvature, 5,730 ft. radius—*Continued.*

Δ		Tang., T.	Ext. dist., E.	Long chord, L. C.	Δ		Tang., T.	Ext. dist., E.	Long chord, L. C.
°	′				°	′			
17	00	856.30	63.634	1693.8	25	00	1270.2	139.11	2480.2
	10	864.82	64.900	1710.3		10	1279.0	141.01	2496.5
	20	873.35	66.178	1726.8		20	1287.7	142.93	2512.8
	30	881.88	67.470	1743.2		30	1296.5	144.85	2529.0
	40	890.41	68.774	1759.7		40	1305.3	146.79	2545.3
	50	898.95	70.091	1776.2		50	1314.0	148.75	2561.5
18	00	907.49	71.421	1792.6	26	00	1322.8	150.71	2577.8
	10	916.03	72.764	1809.1		10	1331.6	152.69	2594.0
	20	924.58	74.119	1825.5		20	1340.4	154.69	2610.3
	30	933.13	75.488	1842.0		30	1349.2	156.70	2626.5
	40	941.69	76.869	1858.4		40	1358.0	158.72	2642.7
	50	950.25	78.261	1874.9		50	1366.8	160.76	2658.9
19	00	958.81	79.671	1891.3	27	00	1375.6	162.81	2675.1
	10	967.38	81.092	1907.8		10	1384.4	164.87	2691.3
	20	975.96	82.525	1924.2		20	1393.2	166.95	2707.5
	30	984.53	83.972	1940.6		30	1402.0	169.04	2723.7
	40	993.12	85.431	1957.1		40	1410.9	171.15	2739.9
	50	1001.70	86.904	1973.5		50	1419.7	173.27	2756.1
20	00	1010.29	88.389	1989.9	28	00	1428.6	175.41	2772.3
	10	1018.89	89.888	2006.3		10	1437.4	177.55	2788.4
	20	1027.49	91.399	2022.7		20	1446.3	179.72	2804.6
	30	1036.09	92.924	2039.1		30	1455.1	181.89	2820.7
	40	1044.70	94.462	2055.5		40	1464.0	184.08	2836.9
	50	1053.31	96.013	2071.9		50	1472.9	186.29	2853.0
21	00	1061.9	97.58	2088.3	29	00	1481.8	188.51	2869.2
	10	1070.6	99.15	2104.7		10	1490.7	190.74	2885.3
	20	1079.2	100.75	2121.1		20	1499.6	192.99	2901.4
	30	1087.8	102.35	2137.4		30	1508.5	195.25	2917.6
	40	1096.4	103.97	2153.8		40	1517.4	197.53	2933.7
	50	1105.1	105.60	2170.2		50	1526.3	199.82	2949.8
22	00	1113.7	107.24	2186.5	30	00	1535.3	202.12	2965.9
	10	1122.4	108.90	2202.9		10	1544.2	204.44	2982.0
	20	1131.0	110.57	2219.2		20	1553.1	206.77	2998.1
	30	1139.7	112.25	2235.6		30	1562.1	209.12	3014.2
	40	1148.4	113.95	2251.9		40	1571.0	211.48	3030.2
	50	1157.0	115.66	2268.3		50	1580.0	213.86	3046.3
23	00	1165.7	117.38	2284.6	31	00	1589.0	216.25	3062.4
	10	1174.4	119.12	2301.0		10	1598.0	218.66	3078.4
	20	1183.1	120.87	2317.3		20	1606.9	221.08	3094.5
	30	1191.8	122.63	2333.6		30	1615.9	223.51	3110.5
	40	1200.5	124.41	2349.9		40	1624.9	225.96	3126.6
	50	1209.2	126.20	2366.2		50	1633.9	228.42	3142.6
24	00	1217.9	128.00	2382.5	32	00	1643.0	230.90	3158.6
	10	1226.6	129.82	2398.8		10	1652.0	233.39	3174.6
	20	1235.3	131.65	2415.1		20	1661.0	235.90	3190.6
	30	1244.0	133.50	2431.4		30	1670.0	238.43	3206.6
	40	1252.8	135.36	2447.7		40	1679.1	240.96	3222.6
	50	1261.5	137.23	2464.0		50	1688.1	243.52	3238.6

TABLE XII.—**Elements of a circular curve of 1° curvature, 5,730 ft. radius**—*Continued.*

Δ		Tang., T.	Ext. dist., E.	Long chord, L. C.	Δ		Tang., T.	Ext. dist., E.	Long chord, L. C.
°	′				°	′			
33	00	1697.2	246.08	3254.6	41	00	2142.2	387.38	4013.1
	10	1706.3	248.66	3270.6		10	2151.7	390.71	4028.7
	20	1715.3	251.26	3286.6		20	2161.2	394.06	4044.3
	30	1724.4	253.87	3302.5		30	2170.8	397.43	4059.9
	40	1733.5	256.50	3318.5		40	2180.3	400.82	4075.5
	50	1742.6	259.14	3334.4		50	2189.9	404.22	4091.1
34	00	1751.7	261.80	3350.4	42	00	2199.4	407.64	4106.6
	10	1760.8	264.47	3366.3		10	2209.0	411.07	4122.2
	20	1770.0	267.16	3382.2		20	2218.6	414.52	4137.7
	30	1779.1	269.86	3398.2		30	2228.1	417.99	4153.3
	40	1788.3	272.58	3414.1		40	2237.7	421.48	4168.8
	50	1797.4	275.31	3430.0		50	2247.3	424.98	4184.3
35	00	1806.6	278.05	3445.9	43	00	2257.0	428.50	4199.8
	10	1815.7	280.82	3461.8		10	2266.6	432.04	4215.3
	20	1824.9	283.60	3477.7		20	2276.2	435.59	4230.8
	30	1834.1	286.39	3493.5		30	2285.9	439.16	4246.3
	40	1843.3	289.20	3509.4		40	2295.6	442.75	4261.8
	50	1852.5	292.02	3525.3		50	2305.2	446.35	4277.3
36	00	1861.7	294.86	3541.1	44	00	2314.9	449.98	4292.7
	10	1870.9	297.72	3557.0		10	2324.6	453.62	4308.2
	20	1880.1	300.59	3572.8		20	2334.3	457.27	4323.6
	30	1889.4	303.47	3588.6		30	2344.1	460.95	4339.0
	40	1898.6	306.37	3604.5		40	2353.8	464.64	4354.5
	50	1907.9	309.29	3620.3		50	2363.5	468.35	4369.9
37	00	1917.1	312.22	3636.1	45	00	2373.3	472.08	4385.3
	10	1926.4	315.17	3651.9		10	2383.1	475.82	4400.7
	20	1935.7	318.13	3667.7		20	2392.8	479.59	4416.1
	30	1945.0	321.11	3683.5		30	2402.6	483.37	4431.4
	40	1954.3	324.11	3699.3		40	2412.4	487.16	4446.8
	50	1963.6	327.12	3715.0		50	2422.3	490.98	4462.2
38	00	1972.9	330.15	3730.8	46	00	2432.1	494.82	4477.5
	10	1982.2	333.19	3746.5		10	2441.9	498.67	4492.8
	20	1991.5	336.25	3762.3		20	2451.8	502.54	4508.2
	30	2000.9	339.32	3778.0		30	2461.7	506.42	4523.5
	40	2010.2	342.41	3793.8		40	2471.5	510.33	4538.8
	50	2019.6	345.52	3809.5		50	2481.4	514.25	4554.1
39	00	2029.0	348.64	3825.2	47	00	2491.3	518.20	4569.4
	10	2038.4	351.78	3840.9		10	2501.2	522.16	4584.7
	20	2047.8	354.94	3856.6		20	2511.2	526.13	4599.9
	30	2057.2	358.11	3872.3		30	2521.1	530.13	4615.2
	40	2066.6	361.29	3888.0		40	2531.1	534.15	4630.4
	50	2076.0	364.50	3903.6		50	2541.0	538.18	4645.7
40	00	2085.4	367.72	3919.3	48	00	2551.0	542.23	4660.9
	10	2094.9	370.95	3935.0		10	2561.0	546.30	4676.1
	20	2104.3	374.20	3950.6		20	2571.0	550.39	4691.3
	30	2113.8	377.47	3966.3		30	2581.0	554.50	4706.5
	40	2123.3	380.76	3981.9		40	2591.1	558.63	4721.7
	50	2132.7	384.06	3997.5		50	2601.1	562.77	4786.9

TABLE XII.—Elements of a circular curve of 1° curvature, 5,730 ft. radius—*Continued.*

Δ		Tang., T.	Ext. dist., E.	Long chord, L. C.	Δ		Tang., T.	Ext. dist., E.	Long chord, L. C.
°	′				°	′			
49	00	2611.2	566.94	4752.1	57	00	3110.9	790.08	5467.9
	10	2621.2	571.12	4767.3		10	3121.7	795.24	5482.5
	20	2631.3	575.32	4782.4		20	3132.6	800.42	5497.2
	30	2641.4	579.54	4797.5		30	3143.4	805.62	5511.8
	40	2651.5	583.78	4812.7		40	3154.2	810.85	5526.4
	50	2661.6	588.04	4827.8		50	3165.1	816.10	5541.0
50	00	2671.8	592.32	4842.9	58	00	3176.0	821.37	5555.6
	10	2681.9	596.62	4858.0		10	3186.9	826.66	5570.2
	20	2692.1	600.93	4873.1		20	3197.8	831.98	5584.7
	30	2702.3	605.27	4888.2		30	3208.8	837.31	5599.3
	40	2712.5	609.62	4903.2		40	3219.7	842.67	5613.8
	50	2722.7	614.00	4918.3		50	3230.7	848.06	5628.3
51	00	2732.9	618.39	4933.4	59	00	3241.7	853.46	5642.8
	10	2743.1	622.81	4948.4		10	3252.7	858.89	5657.3
	20	2753.4	627.24	4963.4		20	3263.7	864.34	5671.8
	30	2763.7	631.69	4978.4		30	3274.8	869.82	5686.3
	40	2773.9	636.16	4993.4		40	3285.8	875.32	5700.8
	50	2784.2	640.66	5008.4		50	3296.9	880.84	5715 2
52	00	2794.5	645.17	5023.4	60	00	3308.0	886.38	5729.7
	10	2804.9	649.70	5038.4		10	3319.1	891.95	5744.1
	20	2815.2	654.25	5053.4		20	3330.3	897.54	5758.5
	30	2825.6	658.83	5068.3		30	3341.4	903.15	5772.9
	40	2835.9	663.42	5083.3		40	3352.6	908.79	5787.3
	50	2846.3	668.03	5098.2		50	3363.8	914.45	5801.7
53	00	2856.7	672.66	5113.1	61	00	3375.0	920.14	5816.0
	10	2867.1	677.32	5128.0		10	3386.3	925.85	5830.4
	20	2877.5	681.99	5142.9		20	3397.5	931.58	5844.7
	30	2888.0	686.68	5157.8		30	3408.8	937.34	5859.1
	40	2898.4	691.40	5172.7		40	3420.1	943.12	5873.4
	50	2908.9	696.13	5187.6		50	3431.4	948.92	5887.7
54	00	2919.4	700.89	5202.4	62	00	3442.7	954.75	5902.0
	10	2929.9	705.66	5217.3		10	3454.1	960.60	5916.3
	20	2940.4	710.46	5232.1		20	3465.4	966.48	5930.5
	30	2951.0	715.28	5246.9		30	3476.8	972.39	5944.8
	40	2961.5	720.11	5261.7		40	3488.2	978.31	5959.0
	50	2972.1	724.97	5276.5		50	3499.7	984.27	5973.3
55	00	2982.7	729.85	5291.8	63	00	3511.1	990.24	5987.5
	10	2993.3	734 76	5306.1		10	3522.6	996.24	6001.7
	20	3003.9	739.68	5320.9		20	3534.1	1002.3	6015.9
	30	3014.5	744.62	5335.6		30	3545.6	1008.3	6030.0
	40	3025.2	749.59	5350.4		40	3557.2	1014.4	6044.2
	50	3035.8	754.57	5365.1		50	3568.7	1020.5	6058.4
56	00	3046.5	759.58	5379 8	64	00	3580.3	1026.6	6072.5
	10	3057.2	764.61	5394.5		10	3591.9	1032.8	6086.6
	20	3067.9	769.66	5409.2		20	3603.5	1039.0	6100.7
	30	3078.7	774.73	5423.9		30	3615.1	1045.2	6114.8
	40	3089.4	779.83	5438.6		40	3626.8	1051.4	6128.9
	50	3100.2	784.94	5453.3		50	3638.5	1057.7	6143.0

TABLE XII.—**Elements of a circular curve** of 1° curvature, 5,730 ft. radius—*Continued.*

Δ		Tang., T.	Ext. dist., E.	Long chord, L. C.	Δ		Tang., T.	Ext. dist., E.	Long chord, L. C.
°	′				°	′			
65	00	3650.2	1063.9	6157.1	73	00	4239.7	1398.0	6816.3
	10	3661.9	1070.2	6171.1		10	4252.6	1405.7	6829.6
	20	3673.7	1076.6	6185.2		20	4265.6	1413.5	6843.0
	30	3685.4	1082.9	6199.2		30	4278.5	1421.2	6856.4
	40	3697.2	1089.3	6213.2		40	4291.5	1429.0	6869.7
	50	3709.0	1095.7	6227.2		50	4304.6	1436.8	6883.1
66	00	3720.9	1102.2	6241.2	74	00	4317.6	1444.6	6896.4
	10	3732.7	1108.6	6255.2		10	4330.7	1452.5	6909.7
	20	3744.6	1115.1	6269.1		20	4343.8	14 0.4	6923.0
	30	3756.5	1121.7	6283.1		30	4356.9	1468.4	6936.2
	40	3768.5	1128.2	6297.0		40	4370.1	1476.4	6949.5
	50	3780.4	1134.8	6310.9		50	4383.3	1484.4	6962.8
67	00	3792.4	1141.4	6324.8	75	00	4396.5	1492.4	6976.0
	10	3804.4	1148.0	6338.7		10	4409.8	1500.5	6989.2
	20	3816.4	1154.7	6352.6		20	4423.1	1508.6	7002.4
	30	3828.4	1161.3	6366.4		30	4436.4	1516.7	7015.6
	40	3840.5	1168.1	6380.3		40	4449.7	1524.9	7028.8
	50	3852.6	1174.8	6394.1		50	4463.1	1533.1	7041.9
68	00	3864.7	1181.6	6408.0	76	00	4476.5	1541.4	7055.0
	10	3876.8	1188.4	6421.8		10	4489.9	1549.7	7068.2
	20	3889.0	1195.2	6435.6		20	4503.4	1558.0	7081.3
	30	3901.2	1202.0	6449.4		30	4 16.9	1566.3	7094.4
	40	3913.4	1208.9	6463.1		40	4530.4	1574.7	7107.5
	50	3925.6	1215.8	6476.9		50	4544.0	1583.1	7120.5
69	00	3937.9	1222.7	6490.6	77	00	4557.6	1591.6	7133.6
	10	3950.2	1229.7	6504.4		10	4571.2	1600.1	7146.6
	20	3962.5	1236.7	6518.1		20	4584.8	1608.6	7159.6
	30	3974.8	1243.7	6531.8		30	4598.5	1617.1	7172.6
	40	3987.2	1250.8	6545.5		40	461 .2	1625.7	7185.6
	50	3999.5	1257.	6559.1		50	4626.0	1634.4	7198.6
70	00	4011.9	1265.0	6572.8	78	00	4639.8	1643.0	7211.6
	10	4024.4	1272.1	6586.4		10	4653.6	1651.7	7224.5
	20	4036.8	1279.3	6600.1		20	4667.4	1660.5	7237.4
	30	4049.3	1286.5	6613.7		30	4681.3	1669.2	7250.4
	40	4061.8	1293.7	6627.3		40	4695.2	1678.1	7263.3
	50	4074.4	1300.9	6640.9		50	4709.2	1686.9	7276.1
71	00	4086.9	1308.2	6654.4	79	00	4723.2	1695.8	7289.0
	10	4099.5	1315.5	6668.0		10	4737.2	1704.7	7301.9
	20	4112.1	1322.9	6681.6		20	4751.2	1713.7	7314.7
	30	4124.8	1330.3	6695.1		30	4765.3	1722.7	7327.5
	40	4137.4	1337.7	6708.6		40	4779.4	1731.7	7340.3
	50	4150.1	1345.1	6722.1		50	4793.6	1740.8	7353.1
72	00	4162.8	1352.6	6735.6	80	00	4808.7	1749.9	7365.9
	10	4175.6	1360.1	6749.1		10	4822.0	1759.0	7378.7
	20	4188.4	1367.6	6762.5		20	4836.2	1768.2	7391.4
	30	4201.2	1375.2	6776.0		30	4850.5	1777.4	7404.1
	40	4214.0	1382.8	6789.4		40	4864.8	1786.7	7416.8
	50	4226.8	1390.4	6802.8		50	4879.2	1796.0	7429.5

TABLE XII.—**Elements of a circular curve of 1° curvature, 5,730 ft. radius**—*Concluded.*

Δ		Tang., T.	Ext. dist., E.	Long chord, L. C.	Δ		Tang., T.	Ext. dist., E.	Long chord, L. C.
°	′				°	′			
81	00	4893.6	1805.3	7442.2	86	00	5343.0	2104.7	7815.2
	10	4908.0	1814.7	7454.9		10	5358.6	2115.3	7827.4
	20	4922.5	1824.1	7467.5		20	5374.2	2126.0	7839.6
	30	4937.0	1833.6	7480.2		30	5389.9	2136.7	7851.7
	40	4951.5	1843.1	7492.8		40	5405.6	2147.5	7863.8
	50	4966.1	1852.6	7505.4		50	5421.4	2158.4	7876.0
82	00	4980.7	1862.2	7518.0	87	00	5437.2	2169.2	7888.1
	10	4995.4	1871.8	7530.5		10	5453.1	2180.2	7900.1
	20	5010.0	1881.5	7543.1		20	5469.0	2191.1	7912.2
	30	5024.8	1891.2	7555.6		30	5484.9	2202.2	7924.3
	40	5039.5	1900.9	7568.2		40	5500.9	2213.2	7936.3
	50	5054.3	1910.7	7580.7		50	5517.0	2224.3	7948.3
83	00	5069.2	1920.5	7593.2	88	00	5533.1	2235.5	7960.3
	10	5084.0	1930.4	7605.6		10	5549.2	2246.7	7972.3
	20	5099.0	1940.3	7618.1		20	5565.4	2258.0	7984.2
	30	5113.9	1950.3	7630.5		30	5581.6	2269.3	7996.2
	40	5128.9	1960.2	7643.0		40	5597.8	2280.6	8008.1
	50	5143.9	1970.3	7655.4		50	5614.2	2292.0	8020.0
84	00	5159.0	1980.4	7667.8	89	00	5630.5	2303.5	8031.9
	10	5174.1	1990.5	7680.1		10	5646.9	2315.0	8043.8
	20	5189.3	2000.6	7692.5		20	5663.4	2326.6	8055.7
	30	5204.4	2010.8	7704.9		30	5679.9	2338.2	8067.5
	40	5219.7	2021.1	7717.2		40	5696.4	2349.8	8079.3
	50	5234.9	2031.4	7729.5		50	5713.0	2361.5	8091.2
85	00	5250.3	2041.7	7741.8	90	00	5729.7	2373.3	8103.0
	10	5265.6	2052.1	7754.1		10	5746.3	2385.1	8114.7
	20	5281.0	2062.5	7766.3		20	5763.1	2397.0	8126.5
	30	5296.4	2073.0	7778.6		30	5779.9	2408.9	8138.2
	40	5311.9	2083.5	7790.8		40	5796.7	2420.9	8150.0
	50	5327.4	2094.1	7803.0		50	5813.6	2432.9	8161.7

Note.—If $\Delta \times D$ is less than 600, the error in **tang. dist.** of the above table is less than 0.4 ft. If $\Delta \times D$ is less than 400, the error in tang. dist. is less than 0.25 ft. If $\Delta \times D$ is less than 200, the error in tang. dist. is less than 0.1 ft.

TABLE XV.—**Middle ordinates** for curving rails (feet).

Radius (feet).	Length of rail chords.											
	32	30	28	26	24	22	20	18	16	14	12	10
5,730	0.022	0.020	0.017	0.015	0.013	0.011	0.009	0.007	0.006	0.004	0.003	0.002
2,865	.045	.039	.034	.030	.025	.021	.017	.014	.011	.009	.006	.004
1,910	.067	.059	.051	.044	.038	.032	.026	.021	.017	.013	.009	.007
1,432	.089	.079	.068	.059	.050	.042	.035	.028	.022	.017	.013	.009
1,146	.112	.098	.086	.074	.063	.053	.044	.035	.028	.021	.016	.011
955	.134	.118	.103	.088	.075	.063	.052	.042	.034	.026	.019	.013
819	.156	.137	.120	.103	.088	.074	.061	.049	.039	.030	.022	.015
716	.179	.157	.137	.118	.100	.084	.070	.057	.045	.034	.025	.017
637	.201	.177	.154	.133	.113	.095	.078	.064	.050	.038	.028	.020
573	.223	.196	.171	.147	.126	.106	.087	.071	.056	.043	.031	.022
521	.245	.216	.188	.162	.138	.116	.096	.078	.061	.047	.035	.024
477	.268	.235	.205	.177	.151	.127	.105	.085	.067	.051	.038	.026
409	.312	.274	.238	.206	.175	.147	.122	.099	.078	.060	.044	.030
357	.356	.313	.273	.235	.200	.168	.139	.113	.089	.068	.050	.035
318	.400	.352	.307	.264	.225	.189	.156	.127	.100	.077	.056	.039
286	.445	.391	.340	.293	.250	.210	.174	.141	.111	.085	.063	.043
225	.57	.50	.44	.38	.32	.27	.22	.18	.14	.11	.08	.05
200	.64	.56	.49	.42	.36	.30	.25	.20	.16	.12	.09	.06
175	.73	.64	.56	.49	.41	.35	.29	.24	.18	.13	.10	.06
150	.86	.75	.65	.56	.48	.40	.33	.27	.21	.16	.12	.09
125	1.03	.90	.79	.68	.58	.49	.40	.32	.26	.20	.15	.10
100	1.31	1.13	.98	.85	.73	.61	.51	.41	.33	.25	.18	.13
80	1.62	1.42	1.28	1.06	.91	.76	.63	.51	.41	.32	.23	.16
60	2.17	1.91	1.74	1.42	1.21	1.09	.84	.68	.54	.41	.30	.21
50	2.63	2.31	2.00	1.73	1.46	1.23	1.01	.82	.73	.49	.36	.25
30	4.62	4.02	3.47	2.96	2.51	2.09	1.72	1.38	1.09	.83	.61	.42

TABLE XVI.—**Increase in gage** of track on **curves.**

Degree of curve.	Increase over standard gage.	Gage of track.	Distance of guard rail from main rail.
Less than 3°	0 in	4 ft. 8½ ins	1¾ ins.
3°	⅛ in	4 ft. 8⅝ ins	1⅞ ins.
5°	¼ in	4 ft. 8⅞ ins	1⅞ ins.
7°	⅜ in	4 ft. 8¾ ins	2 ins.
9°	½ in	4 ft. 8⅞ ins	2⅛ ins.
11°	⅝ in	4 ft. 9 ins	2¼ ins.
13°	¾ in	4 ft. 9⅛ ins	2⅜ ins.
15°	⅞ in	4 ft. 9¼ ins	2½ ins.
17°	1 in	4 ft. 9⅜ ins	2⅝ ins.
19°	1⅛ ins	4 ft. 9½ ins	2¾ ins.
21°		4 ft. 9⅝ ins	2⅞ ins.

TABLE XVII.—Bill of **material for standard pile bridges.**

Details.	16-ft. span.																			
	For 1 span.	For 2 spans.	For 3 spans.	For 4 spans.	For 5 spans.	For 6 spans.	For 7 spans.	For 8 spans.	For 9 spans.	For 10 spans.	For 11 spans.	For 12 spans.	For 13 spans.	For 14 spans.	For 15 spans.	For 16 spans.	For 17 spans.	For 18 spans.	For 19 spans.	For 20 spans.	For each addl. span.
Piles:																					
End bents	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	---
Int. bents	---	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	5
Caps, white pine, 14 by 14 ins., 14 ft. long	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	1
Sway braces, white pine, 4 by 10 ins*	---	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	2
Stringers, Douglas fir, 8 by 16 ins.:																					
16 ft. long	6	---	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	---
32 ft. long	---	6	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	3
Ties, white pine, S 1 S, 8 by 8 ins., 10 ft. long	15	29	43	57	71	85	99	113	127	141	155	169	183	197	211	225	239	253	267	281	14
Guard rails, white pine, S 1 S, 4 by 10 ins., 16 ft. long	2	5	7	9	11	14	16	18	20	22	25	27	29	31	33	36	38	40	42	45	2
Stringer bolts (square heads and nuts), ¾ in. diameter, 3 ins. threaded, 35 ins. long	4	8	20	28	36	44	52	60	68	76	84	92	100	108	116	124	132	140	148	156	8
Floor bolts (square heads and nuts), ¾ in. diameter, 3 ins. threaded, 44½ ins. long	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	2
Sway-brace bolts (square heads and nuts), ¾ in. diameter, 3½ ins. threaded:																					
21 ins. long	---	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	10
25 ins. long	---	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1
Packing spools	8	16	40	56	72	88	104	120	136	152	168	184	200	216	232	248	264	280	296	312	16
Standard cast slot washers for ¾-in. bolts	16	50	100	142	184	226	268	310	352	394	436	478	520	562	604	646	688	730	772	814	42

TABLE XVII.—Bill of material for standard pile bridges—*Continued.*

Driftbolts, ¾ in. diameter, 22 ins. long	8	13	18	23	28	33	38	43	48	53	58	63	68	73	78	83	88	93	98	103	5
Spikes:																					
⅝ in. by 14 ins. long	13	22	31	40	49	58	67	76	85	94	103	112	121	130	139	148	157	166	175	184	9
½ in. by 10 ins. long	28	56	84	112	140	168	196	224	252	280	308	336	364	392	420	448	476	504	532	560	28
BULKHEADS.																					
Furring strips, 2 by 4 ins., 3 ft. 4 ins. long (cut from four 10-ft. lengths)	12	Alike for all bridges.																			
Planks, 3 by 10 ins.:																					
14 ft. long	2																				
16 ft. long	6																				
Spikes, 10 ins. long (planks to bents)	48																				
Nails, 4½ ins. long (strips to bents)	24																				

* Height of bridge ft.	10 to 12	13 to 15	16 to 18	19 to 20
* Length of brace ft.	16	18	20	22

TABLE XVIII.—**Switch leads and distances** (circular throughout).

Gage, 2 ft. 6 ins. Throw, 4 ins. = 0.333 ft.

Frog No.	Frog angle.			Distance, BF.	Chord, *af*.	Switch length.	Radius.	Logarithm.	Degree of curve.		
	°	′	″	*Ft.*	*Ft.*	*Ft.*	*Ft.*		°	′	″
4	14	15	00	20.0	19.85	7.30	80.00	1.90309	77	20	06
4½	12	40	49	22.5	22.35	8.21	101.25	2.00539	59	11	12
5	11	25	16	25.0	24.88	9.12	125.00	2.09691	47	09	28
5½	10	23	20	27.5	27.38	10.03	151.25	2.18256	38	20	38
6	9	31	39	30.0	29.89	10.94	180.00	2.25527	32	15	20
6½	8	47	51	32.5	32.40	11.86	211.25	2.32480	27	21	56
7	8	10	16	35.0	34.91	12.77	245.00	2.38917	23	33	06
7½	7	37	41	37.5	37.42	13.68	281.25	2.44910	20	28	48
8	7	09	10	40.0	39.92	14.59	320.00	2.50515	17	48	44
8½	6	43	59	42.5	42.43	15.50	361.25	2.55781	15	54	40
9	6	21	35	45.0	44.93	16.42	405.00	2.60746	14	11	00
9½	6	01	32	47.5	47.43	17.33	451.25	2.65442	12	43	22
10	5	43	29	50.0	49.94	18.24	500.00	2.69897	11	28	42
10½	5	27	09	52.5	52.44	19.16	551.25	2.74135	10	24	28
11	5	12	18	55.0	54.94	20.07	605.00	2.78176	9	28	52
11½	4	58	45	57.5	57.44	20.99	661.25	2.82037	8	40	24
12	4	46	19	60.0	59.94	21.90	720.00	2.85733	7	57	50

TABLE XIX.—**Switch leads and distances** (circular throughout).

Gage, 4 ft. 8½ ins. = 4.708 ft. Throw, 5 ins. = 0.417 ft.

No., n.	Angle, F.			Distance, BF.	Chord, af.	Switch, AD.	Radius, r.	Degree of curve.		
	°	′	″					°	′	″
4	14	15	00	37.664	37.373	11.209	150.656	38	45	57
4½	12	40	49	42.372	42.113	12.610	190.674	30	24	09
5	11	25	16	47.080	46.846	14.012	235.400	24	31	36
5½	10	23	20	51.788	51.575	15.413	284.834	20	13	13
6	9	31	39	56.496	56.301	16.814	338.976	16	57	52
6½	8	47	51	61.204	61.024	18.215	397.826	14	26	25
7	8	10	16	65.912	65.744	19.616	461.384	12	26	34
7½	7	37	41	70.620	70.464	21.017	529.650	10	50	02
8	7	09	10	75.328	75.181	22.418	602.624	9	31	07
8½	6	43	59	80.036	79.898	23.820	680.306	8	25	47
9	6	21	35	84.744	84.613	25.221	762.696	7	31	04
9½	6	01	32	89.452	89.328	26.622	849.794	6	44	46
10	5	43	29	94.160	94.043	28.023	941.600	6	05	16
10½	5	27	09	98.868	98.756	29.424	1038.114	5	31	17
11	5	12	18	103.576	103.469	30.825	1139.336	5	01	50
11½	4	58	45	108.284	108.182	32.227	1245.266	4	36	08
12	4	46	19	112.992	112.894	33.628	1355.904	4	13	36

Gage, 3 ft. Throw, 4 ins. = 0.333 ft.

No., n.	Angle, F.			Distance, BF.	Chord, af.	Switch, AD.	Radius, r.	Degree of curve.		
	°	′	″					°	′	″
4	14	15	00	24	23.815	8	96.0	62	46	34
4½	12	40	49	27	26.835	9	121.5	48	36	04
5	11	25	16	30	29.851	10	150.0	38	56	33
5½	10	23	20	33	32.865	11	181.5	31	58	55
6	9	31	39	36	35.876	12	216.0	26	46	07
6½	8	47	51	39	38.885	13	253.5	22	45	04
7	8	10	16	42	41.893	14	294.0	19	35	01
7½	7	37	41	45	44.900	15	337.5	17	02	21
8	7	09	10	48	47.906	16	384.0	14	57	48
8½	6	43	59	51	50.912	17	433.5	13	14	47
9	6	21	35	54	53.917	18	486.0	11	48	37
9½	6	01	32	57	56.921	19	541.5	10	35	46
10	5	43	29	60	59.925	20	600.0	9	33	38
10½	5	27	09	63	62.929	21	661.5	8	40	12
11	5	12	18	66	65.932	22	726.0	7	53	54
11½	4	58	45	69	68.935	[illegible]	793.5	7	13	32
12	4	46	19	72	71.938	24	864.0	6	38	06

Angle and distance of middle frog, F″.

No., n.	No., n″.	Angle, F″.			Distance, aF″.		No., n.	No., n″.	Angle, F″.			Distance, aF″.	
					Gage 4 ft. 8½ ins.	Gage 3 ft.						Gage 4 ft. 8½ ins.	Gage 3 ft.
		°	′	″					°	′	″		
4	2.817	20	07	36	26.736	17.037	8	5.651	10	06	44	53.317	33.974
4½	3.172	17	54	52	30.054	19.151	8½	6.005	9	31	08	56.643	36.094
5	3.527	16	08	19	33.374	21.266	9	6.359	8	59	30	59.969	38.213
5½	3.881	14	40	58	36.695	23.383	9½	6.713	8	31	10	63.296	40.333
6	4.235	13	27	57	40.018	25.500	10	7.067	8	05	40	66.623	42.453
6½	4.589	12	26	07	43.342	27.618	10½	7.420	7	42	35	69.950	44.573
7	4.943	11	33	04	46.666	29.736	11	7.774	7	21	36	73.277	46.693
7½	5.297	10	47	02	49.991	31.855	11½	8.128	7	02	26	76.605	48.813
8	5.651	10	06	44	53.317	33.974	12	8.482	6	44	51	79.932	50.934

TABLE XX.—Grades and grade angles.

Ft. per station.	Ft. per mile.	Inclination.	Ft. per station.	Ft. per mile.	Inclination.	Ft. per station.	Ft. per mile.	Inclination.
		° ′ ″			° ′ ″			° ′ ″
0.01	0.528	0 00 21	0.51	26.928	0 17 32	1.01	53.328	0 34 43
.02	1.056	41	.52	27.456	17 53	1.02	53.856	35 04
.03	1.584	1 02	.53	27.984	18 13	1.03	54.384	35 24
.04	2.112	1 23	.54	28.512	18 34	1.04	54.912	35 45
.05	2.640	1 43	.55	29.040	18 54	1.05	55.440	36 05
.06	3.168	2 04	.56	29.568	19 15	1.06	55.968	36 26
.07	3.696	2 24	.57	30.096	19 36	1.07	56.496	36 47
.08	4.224	2 45	.58	30.624	19 56	1.08	57.024	37 08
.09	4.752	3 06	.59	31.152	20 17	1.09	57.552	37 28
.10	5.280	3 26	.60	31.680	20 38	1.10	58.080	37 49
.11	5.808	3 47	.61	32.208	20 58	1.11	58.608	38 09
.12	6.336	4 08	.62	32.736	21 19	1.12	59.136	38 30
.13	6.864	4 28	.63	33.264	21 39	1.13	59.664	38 51
.14	7.392	4 49	.64	33.792	22 00	1.14	60.192	39 11
.15	7.920	5 09	.65	34.320	22 21	1.15	60.720	39 32
.16	8.448	5 30	.66	34.848	22 41	1.16	61.248	39 53
.17	8.976	5 51	.67	35.376	23 02	1.17	61.776	40 13
.18	9.504	6 11	.68	35.904	23 23	1.18	62.304	40 34
.19	10.032	6 32	.69	36.432	23 43	1.19	62.832	40 54
.20	10.560	6 53	.70	36.960	24 04	1.20	63.360	41 15
.21	11.088	7 13	.71	37.488	24 24	1.21	63.888	41 35
.22	11.616	7 34	.72	38.016	24 45	1.22	64.416	41 56
.23	12.144	7 54	.73	38.544	25 06	1.23	64.944	42 17
.24	12.672	8 15	.74	39.072	25 26	1.24	65.472	42 38
.25	13.200	8 36	.75	39.600	25 47	1.25	66.000	42 58
.26	13.728	8 56	.76	40.128	26 08	1.26	66.528	43 19
.27	14.256	9 17	.77	40.656	26 28	1.27	67.056	43 39
.28	14.784	9 38	.78	41.184	26 49	1.28	67.584	44 00
.29	15.312	9 58	.79	41.712	27 09	1.29	68.112	44 21
.30	15.840	10 19	.80	42.240	27 30	1.30	68.640	44 41
.31	16.368	10 39	.81	42.768	27 51	1.31	69.168	45 02
.32	16.896	11 00	.82	43.296	28 11	1.32	69.696	45 23
.33	17.424	11 21	.83	43.824	28 32	1.33	70.224	45 43
.34	17.952	11 41	.84	44.352	28 53	1.34	70.752	46 04
.35	18.480	12 02	.85	44.880	29 13	1.35	71.280	46 24
.36	19.008	12 23	.86	45.408	29 34	1.36	71.808	46 45
.37	19.536	12 43	.87	45.936	29 54	1.37	72.336	47 06
.38	20.064	13 04	.88	46.464	30 15	1.38	72.864	47 26
.39	20.592	13 24	.89	46.992	30 36	1.39	73.392	47 47
.40	21.120	13 45	.90	47.520	30 57	1.40	73.920	48 08
.41	21.648	14 06	.91	48.048	31 17	1.41	74.448	48 28
.42	22.176	14 26	.92	48.576	31 38	1.42	74.976	48 49
.43	22.704	14 47	.93	49.104	31 58	1.43	75.504	49 09
.44	23.232	15 08	.94	49.632	32 19	1.44	76.032	49 30
.45	23.760	15 28	.95	50.160	32 39	1.45	76.560	49 51
.46	24.288	15 49	.96	50.688	33 00	1.46	77 088	50 11
.47	24.816	16 09	.97	51.216	33 21	1.47	77.616	50 32
.48	25.344	16 30	.98	51.744	33 41	1.48	78.144	50 52
.49	25.872	16 51	.99	52.272	34 02	1.49	78.672	51 13
.50	26.400	17 11	1.00	52.800	34 23	1.50	79.200	51 34

TABLE XX.—Grades and grade angles—*Continued.*

Ft. per station.	Ft. per mile.	Inclination.	Ft. per station.	Ft. per mile.	Inclination.	Ft. per station.	Ft. per mile.	Inclination.
		° ′ ″			° ′ ″			° ′ ″
1.51	79.728	0 51 54	2.05	108.240	1 10 28	5.10	269.280	2 55 10
1.52	80.256	52 15	2.10	110.880	1 12 11	5.20	274.560	2 58 36
1.53	80.784	52 36	2.15	113.520	1 13 54	5.30	279.840	3 02 09
1.54	81.312	52 56	2.20	116.160	1 15 37	5.40	285.120	3 05 27
1.55	81.840	53 17	2.25	118.800	1 17 20	5.50	290.400	3 08 53
1.56	82.368	53 37	2.30	121.440	1 19 03	5.60	295.680	3 12 19
1.57	82.896	53 58	2.35	124.080	1 20 46	5.70	300.960	3 15 44
1.58	83.424	54 19	2.40	126.720	1 22 29	5.80	306.240	3 19 10
1.59	83.952	54 39	2.45	129.360	1 24 12	5.90	311.520	3 22 36
1.60	84.480	55 00	2.50	132.000	1 25 56	6.00	316.800	3 26 01
1.61	85.008	55 21	2.55	134.640	1 27 39	6.10	322.080	3 29 27
1.62	85.536	55 41	2.60	137.280	1 29 22	6.20	327.360	3 32 52
1.63	86.064	56 02	2.65	139.920	1 31 05	6.30	332.640	3 36 18
1.64	86.592	56 22	2.70	142.560	1 32 48	6.40	337.920	3 39 43
1.65	87.120	56 43	2.75	145.200	1 34 31	6.50	343.200	3 43 08
1.66	87.648	57 04	2.80	147.840	1 36 14	6.60	348.480	3 46 34
1.67	88.176	57 24	2.85	150.480	1 37 57	6.70	353.760	3 49 59
1.68	88.704	57 45	2.90	153.120	1 39 40	6.80	359.040	3 53 24
1.69	89.232	58 06	2.95	155.760	1 41 23	6.90	364.320	3 56 50
1.70	89.760	58 26	3.00	158.400	1 43 06	7.00	369.600	4 00 15
1.71	90.288	58 47	3.05	161.040	1 44 49	7.10	374.880	4 03 40
1.72	90.816	59 07	3.10	163.680	1 46 32	7.20	380.160	4 07 06
1.73	91.344	59 28	3.15	166.320	1 48 15	7.30	385.440	4 10 31
1.74	91.872	59 49	3.20	168.960	1 49 58	7.40	390.720	4 13 56
1.75	92.400	1 00 09	3.25	171.600	1 51 41	7.50	396.000	4 17 21
1.76	92.928	1 00 30	3.30	174.240	1 53 24	7.60	401.280	4 20 46
1.77	93.456	1 00 51	3.35	176.880	1 55 07	7.70	406.560	4 24 11
1.78	93.984	1 01 11	3.40	179.520	1 56 50	7.80	411.840	4 27 36
1.79	94.512	1 01 32	3.45	182.160	1 58 33	7.90	417.120	4 31 01
1.80	95.040	1 01 52	3.50	184.800	2 00 16	8.00	422.400	4 34 26
1.81	95.568	1 02 13	3.55	187.440	2 01 59	8.10	427.680	4 37 51
1.82	96.096	1 02 34	3.60	190.080	2 03 42	8.20	432.960	4 41 16
1.83	96.624	1 02 54	3.65	192.720	2 05 25	8.30	438.240	4 44 41
1.84	97.152	1 03 15	3.70	195.360	2 07 08	8.40	443.520	4 48 06
1.85	97.680	1 03 35	3.75	198.000	2 08 51	8.50	448.800	4 51 30
1.86	98.208	1 03 56	3.80	200.640	2 10 34	8.60	454.080	4 54 55
1.87	98.736	1 04 17	3.85	203.280	2 12 17	8.70	459.360	4 58 20
1.88	99.264	1 04 37	3.90	205.920	2 14 00	8.80	464.640	5 01 44
1.89	99.792	1 04 58	3.95	208.560	2 15 43	8.90	469.920	5 05 10
1.90	100.320	1 05 19	4.00	211.200	2 17 26	9.00	475.200	5 08 34
1.91	100.848	1 05 39	4.10	216.480	2 20 52	9.10	480.480	5 11 59
1.92	101.376	1 06 00	4.20	221.760	2 24 18	9.20	485.760	5 15 23
1.93	101.904	1 06 20	4.30	227.040	2 27 44	9.30	491.040	5 18 48
1.94	102.432	1 06 41	4.40	232.320	2 31 10	9.40	496.320	5 22 12
1.95	102.960	1 07 02	4.50	237.600	2 34 36	9.50	501.600	5 25 37
1.96	103.488	1 07 22	4.60	242.880	2 38 01	9.60	506.880	5 29 01
1.97	104.016	1 07 43	4.70	248.160	2 41 27	9.70	512.160	5 32 25
1.98	104.544	1 08 04	4.80	253.440	2 44 53	9.80	517.440	5 35 50
1.99	105.072	1 08 24	4.90	258.720	2 48 19	9.90	522.720	5 39 14
2.00	105.600	1 08 45	5.00	264.000	2 51 45	10.00	528.000	5 42 38

Table XXI.—Inches in decimals of a foot.

1/16	3/32	1/8	3/16	1/4	5/16	3/8	1/2	5/8	3/4	7/8
.0052	.0078	.0104	.0156	.0208	.0260	.0313	.0417	.0521	.0625	.0729

1	2	3	4	5	6	7	8	9	10	11
.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167

Table XXII.—Radii and deflections.

Deg.	Radius.	Tan. Def.	Chd. Def.	Def. for 1 ft.	Deg.	Radius.	Tan. Def.	Chd. Def.	Def. for 1 ft.
° ′					° ′				
0 10	34377	.145	.291	0.05	7	819.0	6.105	12.21	2.10
20	17189	.291	.582	0.10	20	781.8	6.395	12.79	2.20
30	11459	.436	.873	0.15	30	764.5	6.540	13.08	2.25
40	8594.4	.582	1.164	0.20	40	747.9	6.685	13.37	2.30
50	6875.5	.727	1.454	0.25	8	716.8	6.976	13.95	2.40
1	5729.6	.873	1.745	0.30	20	688.2	7.266	14.53	2.50
10	4911.2	1.018	2.036	0.35	30	674.7	7.411	14.82	2.55
20	4297.3	1.164	2.327	0.40	40	661.7	7.556	15.11	2.60
30	3819.8	1.309	2.618	0.45	9	637.3	7.846	15.69	2.70
40	3437.9	1.454	2.909	0.50	20	614.6	8.136	16.27	2.80
50	3125.4	1.600	3.200	0.55	30	603.8	8.281	16.56	2.85
2	2864.9	1.745	3.490	0.60	40	593.4	8.426	16.85	2.90
10	2644.6	1.891	3.781	0.65	10	573.7	8.716	17.43	3.00
20	2455.7	2.036	4.072	0.70	30	546.4	9.150	18.30	3.15
30	2292.0	2.181	4.363	0.75	11	521.7	9.585	19.16	3.30
40	2148.8	2.327	4.654	0.80	30	499.1	10.02	20.04	3.45
50	2022.4	2.472	4.945	0.85	12	478.3	10.45	20.91	3.60
3	1910.1	2.618	5.235	0.90	30	459.3	10.89	21.77	3.75
10	1809.6	2.763	5.526	0.95	13	441.7	11.32	22.64	3.90
20	1719.1	2.908	5.817	1.00	30	425.4	11.75	23.51	4.05
30	1637.3	3.054	6.108	1.05	14	410.3	12.18	24.37	4.20
40	1562.9	3.199	6.398	1.10	30	396.2	12.62	25.24	4.35
50	1495.0	3.345	6.689	1.15	15	383.1	13.05	26.11	4.50
4	1432.7	3.490	6.980	1.20	30	370.8	13.49	26.97	4.65
10	1375.4	3.635	7.271	1.25	16	359.3	13.92	27.84	4.80
20	1322.5	3.718	7.561	1.30	30	348.5	14.35	28.70	4.95
30	1273.6	3.926	7.852	1.35	17	338.3	14.78	29.56	5.10
40	1228.1	4.071	8.143	1.40	18	319.6	15.64	31.29	5.40
50	1185.8	4.217	8.433	1.45	19	302.9	16.51	33.01	5.70
5	1146.3	4.362	8.724	1.50	20	287.9	17.37	34.73	6.00
10	1109.3	4.507	9.014	1.55	21	274.4	18.22	36.44	6.30
20	1074.7	4.653	9.305	1.60	22	262.0	19.08	38.16	6.60
30	1042.1	4.798	9.596	1.65	23	250.8	19.94	39.87	6.90
40	1011.5	4.943	9.886	1.70	24	240.5	20.79	41.58	7.20
50	982.6	5.088	10.18	1.75	25	231.0	21.64	43.28	7.50
6	955.4	5.234	10.47	1.80	26	222.3	22.50	44.99	7.80
10	929.6	5.379	10.76	1.85	27	214.2	23.35	46.69	8.10
20	905.1	5.524	11.05	1.90	28	206.7	24.19	48.38	8.40
30	881.9	5.669	11.34	1.95	29	199.7	25.04	50.07	8.70
40	859.9	5.814	11.63	2.00	30	193.2	25.88	51.76	9.00

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